

## ANALYSIS OF TENSILE TEST DATA

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May 25, 1995

This paper presents some analysis and comment on the December, 1992 tensile tests of the Kevlar fabric used in making the 71" vacuum windows for KTEV. The main goal of the test was to determine the clamping force needed to hold the window by comparing tensile tests of samples of the material in grippers modeled like the actual design flanges. A secondary goal would have been to look for the maximum tensile strength of the material. Samples were tested with the fibers on a 45 degree angle to the axis of the force to understand the strength of the weave better. The Instron testing machine in the Materials Development Lab was used for these tests.

Calculations showed that the minimum force the clamping has to support is 6845 pounds force. The tests showed that 250 ft-lbs of torque on the flange bolts would be able to support the needed force. Nine tests were done at 250 ft-lbs of torque with the flanges exactly as the final design and all passed the clamping test. See the attached spreadsheet. The percent elongation at failure of the fabric sample was found to be 50% higher than the published data from DuPont for Kevlar fibers alone. This discrepancy can be explained by the fact that for our tests the fabric does not strain at the same rate as single fibers. The extra length of fibers because of the weave makes the simple measurement of sample length only an approximation which could be in error by as much as 50%.

The spreadsheet also calculates the load per inch of fabric to compare with the published data of the fabric manufacturer. The manufacturer uses ASTM D-1682 to test for breaking loads and elongation of fabrics. We have no elongation figures for the fabric from the manufacturer but they do publish the strength. Their number for this fabric is 1800 pounds force per inch of fabric. If our data set is analyzed the measured number is 966 pounds per inch. The difference is in the samples and tests. In ASTM D-1682 a one inch wide sample is put between grippers that typically grip harder as the tensile force rises and does not require bolts to supply clamping force. The clamping system in our tests does not supply the same level of grip on the samples. In our sample testing scheme what happens is that all of the fibers in the areas of the bolts (50% of the total sample) are not gripped hard enough to test to failure. The aluminum ring is meant to distribute the load of clamping to the areas between the bolts but that force is limited to the amount provided by a specific level of bolt torque. At some level of testing force the fibers can still slip past the aluminum ring. The best example we have of that is test number 21 which didn't use the aluminum o-ring but used the entire flange area for clamping. In that sample it is clear that only 1/2 of the fibers are participating in the test. If the number of LOADED fibers is compared then our tests give a load per inch of 1932 pounds per inch which is comparable to the published data for the fabric. We have kept many of the samples for later visual inspection.

The success of these tests has been indicated by the fact that in none of the later pressure or creep tests has any window shown a tendency to pull out from between the flanges. That was the principal reason for the tests. The secondary reason of measuring the strength of the fabric has shown results in agreement with the published values of the manufacturer.

The conclusions above for the 1992 tests are also supported by the July, 1993 testing. The major difference in the two rounds of tests is that in the second round of tests epoxy was used to better bind the fabric into a more continuous sample, and minimize the effects of the short fibers in the bolt areas. The epoxy was successful in that as seen by the

universally higher failure loads in the second set of samples. All of the windows in later pressure testing have been made with the epoxy bond on the circumference.

# Kevlar Tensile test

Kevlar tensile test results				
Test Number	Strain at	Maximum		
	Failure	Load		
	(inches)	lbs force		
9	0.52	7900		
10	0.47	8100		
12	0.47	11300		
13	0.47	10650		
14	0.54	9900		
15	0.5	9010		
16	0.49	8500		
17	0.41	10210		
18	0.42	11150		
Average of tests	0.47	9525		
Length of test samples	7.964			
Percent strain at failure for the average of tests			5.90155701	percent
Width of sample	9.858			
Load per inch of fabric			966.220329	Lbs/in

**Kevlar Window Tensile Tests**

**Fred Renken**

**12/23/92**

**FNAL RD/MSD Thermal Systems**

**ABSTRACT:**

For the new KTeV 1.8 m window tests were necessary to complete safety requirements and assure the window design would meet the necessary standards. Three different configurations were tensile tested to find the torque values necessary to meet requirements based on calculations. It was found that the use of an aluminum gasket increased the clamping capability but also increased damage to the window materials. Without the gasket the clamping fixture slipped at lower loads but held higher maximum loads. Tests with spacers proved that such assemblies would be very difficult to use. Increasing torques will increase the capability of flanges to hold the fixture.

## INTRODUCTION:

On the new fixed beam target experiment KTev, a 1.8 m diameter vacuum chamber window will be constructed for experimentation. This window, although very like others built in the past, is much larger and so extra safety precautions and documentation is needed. The window is constructed of a kevlar fabric sheet for strength between layers of mylar for protection and vacuum seal.

Three different clamping configurations were tested. The first clamp was the same as the fixture used on previous windows with a soft alloy aluminum gasket to achieve a tight seal and account for tolerances in bulk head construction. The second was to test without the gasket, holding the window between only the two bulk heads. Steel inserts were placed in the test samples to simulate a flat bulkhead. In order to use this configuration much tighter tolerances in the bulk head construction will be necessary in order to achieve a vacuum tight seal. The third test was conducted with metal spacers between the flanges inside the window materials to assure bulkhead strength. These tests required the use of the aluminum gasket.

Several aspects of the window were examined in each test. First, would the clamping assembly itself damage the window materials beyond usefulness by compressive forces cutting through the materials. Second, at what load will the first slip or indication of failure occur. At what clamping force or torque would the necessary load be upheld. Most importantly, what maximum load can be sustained in each configuration. Finally, the overall damages and performance of the test samples used.

The window bulkhead flanges were simulated by preparing samples for a tensile test. The clamps were designed to closely simulate the real flanges with both window assembly bolts and through bolts to the vessel. (See drawing numbers 9220.832.ME-285684 and 9220.832.ME-285674) All bolts would be torqued evenly. For this test sample a minimum load of 6845 lbf would be necessary to meet calculations done in an ANSYS analysis of the window. (Attached) The tensile test provides a unidirectional load rather than an even multi-directional force as in the actual window. The actual window should therefore perform better than these tests would indicate.

## 4

19



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Test Data

Test #	Test Speed	Weave	Torque	First Slip	Max Load	Al dim: see fig		Notes:
	in/min	degrees	ft*lbs	lbf	lbf	X	Y	
Al Gasket used: 250 FT*LBS Torque 4 samples								
1	0.05	90	250	7500	11300	0.15	0.152	
2	0.05	90	250	6300	9900	0.167	0.156	
3	0.05	90	250	7400	10210	0.144	0.152	New Bolts used
4	0.05	90	250	7050	11150	0.136	0.154	
Average:				7062.5	10640	0.149	0.154	
No Aluminum Gasket used.								
1	0.05	90	250	5005	13600	N/A	N/A	No Aluminum Used
2	0.05	90	250	5010	12950	N/A	N/A	No Aluminum Used
3	0.05	90	250	7300	12440	N/A	N/A	No Aluminum Used
4	0.05	90	250	5200	12810	N/A	N/A	No Aluminum Used
Average:				5628.75	12950			
Steel and Aluminum Spacers Used:								
1	0.05	90	250	7050	8000	0.146	0.151	Al Spacers
2	0.05	90	250	5800	6810	0.143	0.157	Steel Spacers
3	0.05	90	250	5700	7005	0.158	0.153	Steel Spacers
4	0.05	90	250	5210	6100	—	—	Used Al Spacers
Average:				5940	6978.75	0.149	0.154	



## OBSERVATIONS:

Based on the best representative sample from each different clamping configuration.

Aluminum gasket 250 ft\*lb with 90° weave. (Test #12)

Kevlar: Failure along aluminum gasket location.  
Failures due to fraying and slip from around bolt holes.

Mylar: Clearly indented along aluminum gasket. No holes or tears.

Data Curve: Smooth with only 2 slips before maximum load reached.

Aluminum gasket 250 ft\*lb with 45° weave. (Tests #19 and #20)

Kevlar: No failure by bolts or aluminum clamp.  
All failure in center region 3.75 inches wide.

Mylar: Some indentation along gasket. One tear at frayed corner.

Data Curve: Apparent yield point exists present.  
Very smooth line without slips or failures until maximum load reached.  
The yield could not be calculated because the load takes a hyperbolic shape for which the cross sectional area is indeterminate.

No aluminum gasket 250 ft\*lb 90° weave. (test #21)

Kevlar: Failure outside clamped regions.  
Failure areas lined up between bolt locations.  
Fraying along edges very evident.

Mylar: Fused slightly to kevlar. Easily removed with very little damage.  
No indentations except slight cloth weave pattern.

Data Curve: Multiple slips and failures before maximum load reached.

Spacers with aluminum gasket at 250 ft\*lb 90° weave. (test #25)

No significant difference in performance of aluminum spacers and steel spacers.

Kevlar: Severe failure along Al gasket. Bolt holes remain intact.  
Little fraying except along edges.

Mylar: Both gasket and spacer indentations visible. No tearing, remained intact.

Spacers: Some seemingly untouched, others severely indented or bent. Aluminum spacers sustained more damage.

Data Curve: Smooth until several failures immediately before maximum load.

## DISCUSSION OF DATA:

All tests had failures resulting from fraying along exposed edges. This would not happen if fabric pulled uniformly in all directions. Fraying would also be reduced with the use of epoxy as all previous windows were constructed. The actual window would be able to sustain higher loads than tensile samples.

45° weave tests formed hyperbolic shaped tension region resulting in higher fraying and indeterminable cross sectional area. Most 45° weave tests results are not helpful contributors to the data desired.

First eleven tests used to find minimal torque at which target loads of 13094 and 6845 lbf would be met or exceeded.

Widespread values of maximum loads indicate tests not completely valid. Experience and design theory should not be blatantly overridden by these results.

Data for the first slip and maximum load included to provide information on which to base safety factors. Fraying edges often the cause for first slip. At this value vacuum may be lost, in the window application, but no severe endangering failure would occur.

Tests in which spacers were used suspect because of the difficulty in assembly of test samples. The difficulty and failure to assemble good samples clearly shown by damage to the mylar and spacers. Better assembly needed than could be done with this test apparatus.

NOTE: Scales change from test to test on graphs so read test curves carefully.

NOTE: The machine could test to a maximum load of 13000 lbf so tests at higher torques were not done.

## CONCLUSIONS:

Tears in mylar pieces was primarily due to slips after the maximum load failure, not from the assembly process. The damage incurred because test was taken to failure. The mylar did become permanently indented.

At 250 ft\*lb a total bolt load of 54395 lbf is exerted on the fixture. The resulting average X dimension on the aluminum gasket of 0.149 yields a compressive force of 37032 psi. This compressive force is higher than mylar's yield and ultimate strengths but failure did not occur since mylar is extremely elastic. This force is below the strength of kevlar so no damage to the cloth was induced by the assembly.

Significantly less damage to the mylar occurred on the tests without the aluminum gasket.

250 ft\*lb torque was necessary with the aluminum gasket to obtain a first slip above the desired 6845 lbf. The first slip for samples without a gasket occurred at a much lower value than either with the gasket or the desired load. Therefore the aluminum gasket significantly aided a secure hold.

The aluminum gasket was not deformed to flush with the clamping fixture and did supply the primary compressive force. This is clearly shown by an average Y of 0.154 which is greater than the maximum 0.145 depth of the slot.

The highest maximum load at 250 ft\*lb torque was attained without the gasket. this would show that the gasket did contribute to failure at maximum loads.

Spacers yielded unacceptable results for both first slip and maximum load. To align all spacers correctly is very difficult and was never done successfully in these tests.

Increased torques would improve the performance of all fixtures and would be reasonable based on past window construction and performance.



45 PSI

K.S2.

ANSYS:

$$T_x = 296280 \text{ lbs}$$

DEC 18 92

$T_x$  PER LINEAR INCH OF THE CIRCUMFERENCE

$$T_{xi} = \frac{296280}{\pi(71)} = 1328.2 \text{ lbs}$$

FOR 9.858 WIDE FIXTURE

$$T_{xg} = \underline{13094} \text{ [lbs]}$$

14.7 PSI

ANSYS:

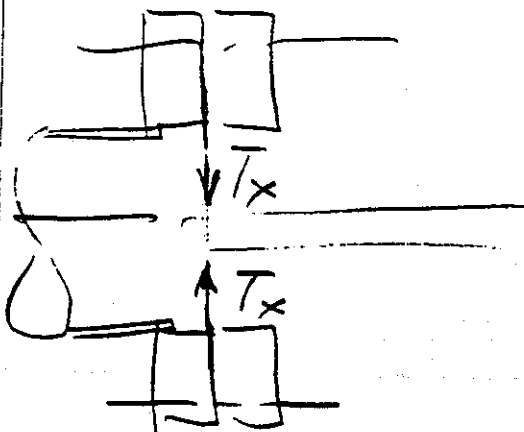
$$T_x = 154880 \text{ lbs}$$

$T_x$  PER LINEAR INCH OF THE CIRCUMFERENCE

$$T_{xi} = \frac{154880}{\pi(71)} = 694.36$$

FOR 9.858 WIDE FIXTURE

$$T_{xg} = \underline{6845} \text{ [lbs]}$$



KEVLAR

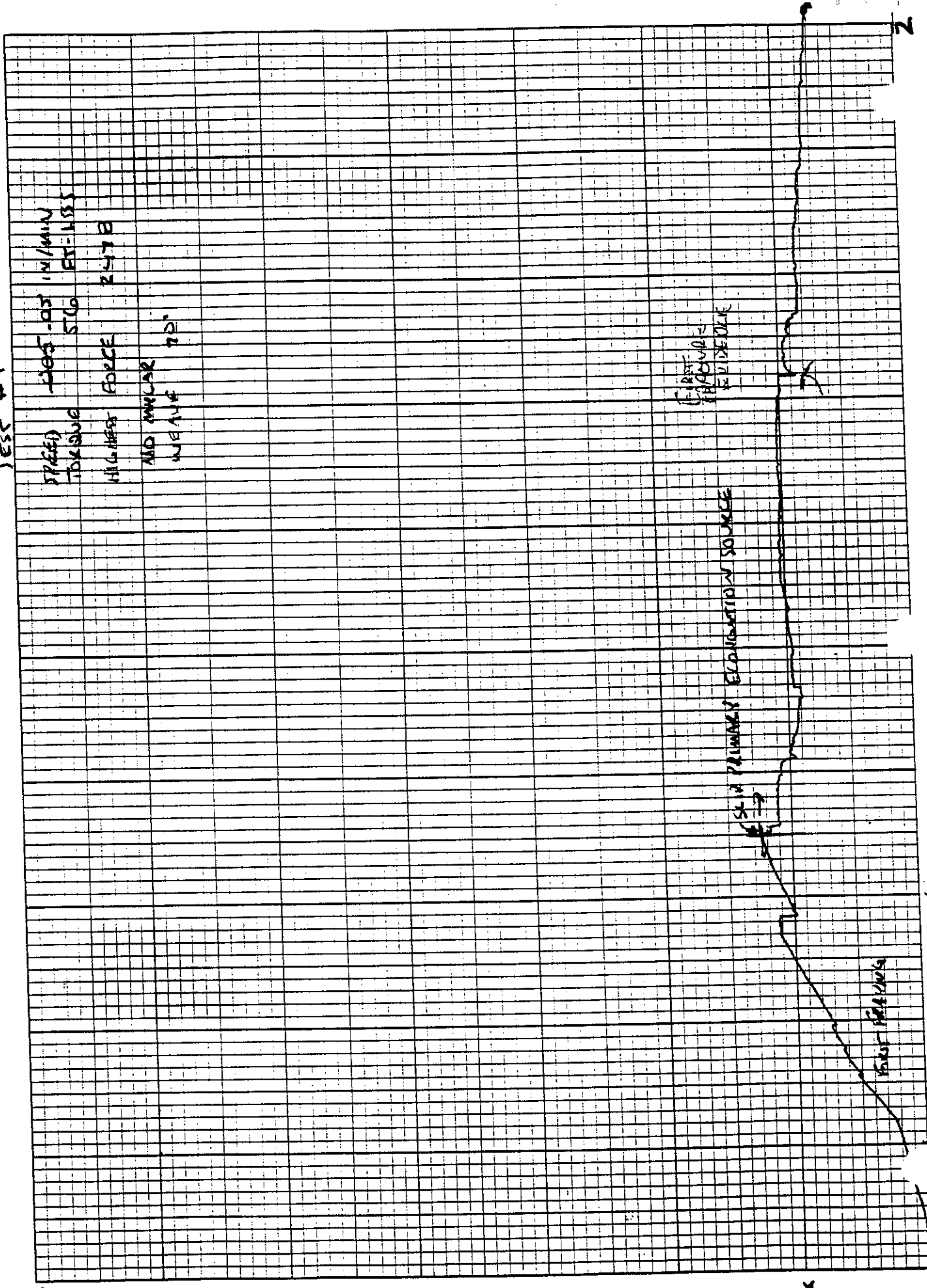
TEST #1

SPRINT 205-05 IN/MIN  
TORSION 516 BT-LBS  
HIGHEST FORCE 2478  
NO APPAR  
WEAVE 72"

TEST  
TORSION  
EVIDENCE

SLIP PRIMARY ELONGATION SOURCE

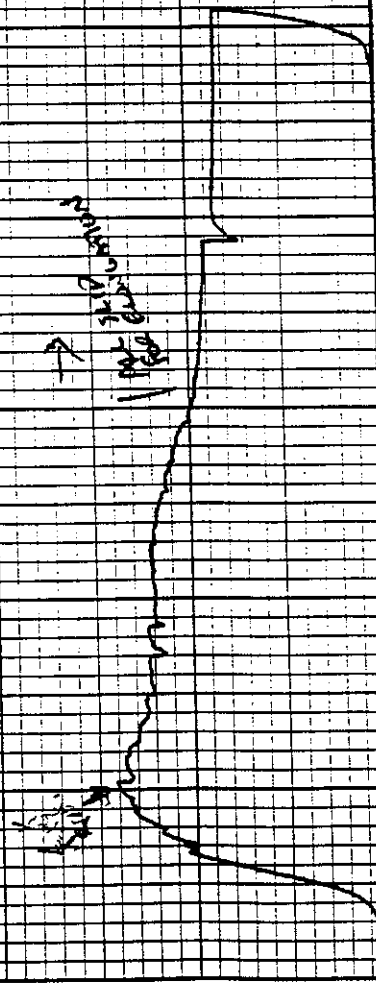
TEST RESULTS



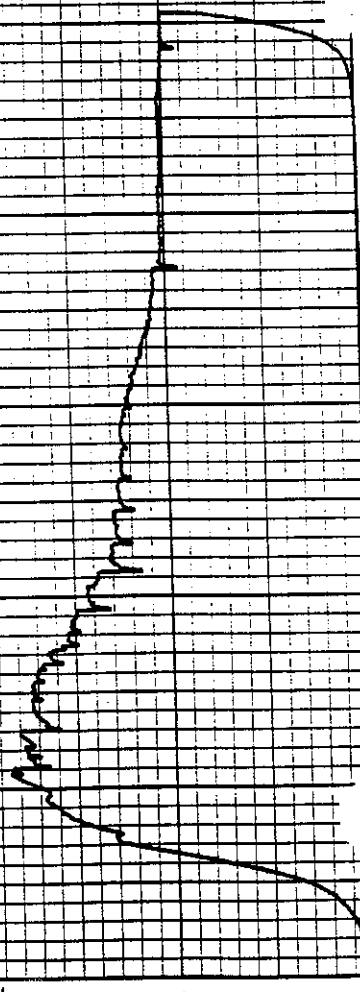
12/3/92

TEST # 2

SPEED 1075 RPM  
TORQUE 83 FT-LB  
MAX FORCE 2510  
WEAVE 70°

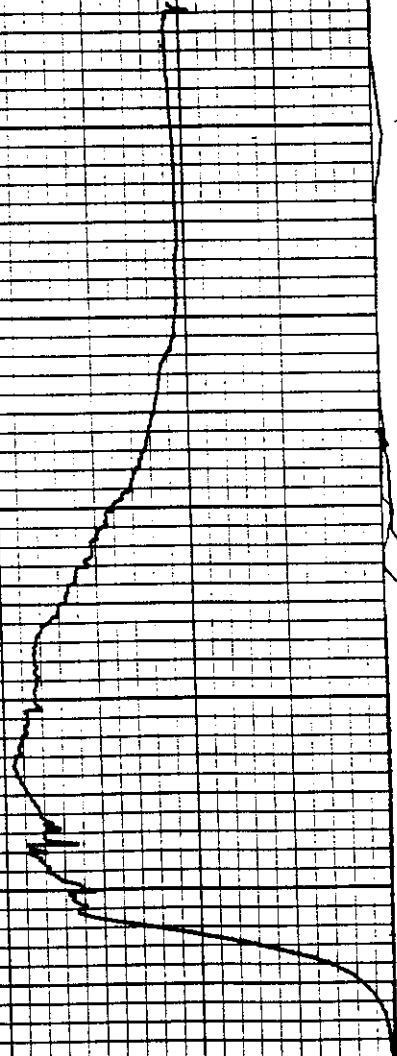


11-13-51  
#3  
SPEED 0.15 MIN/IN  
TORQUE 111 FT-LBS  
MAX FORCE 3700  
WEIGHT 90



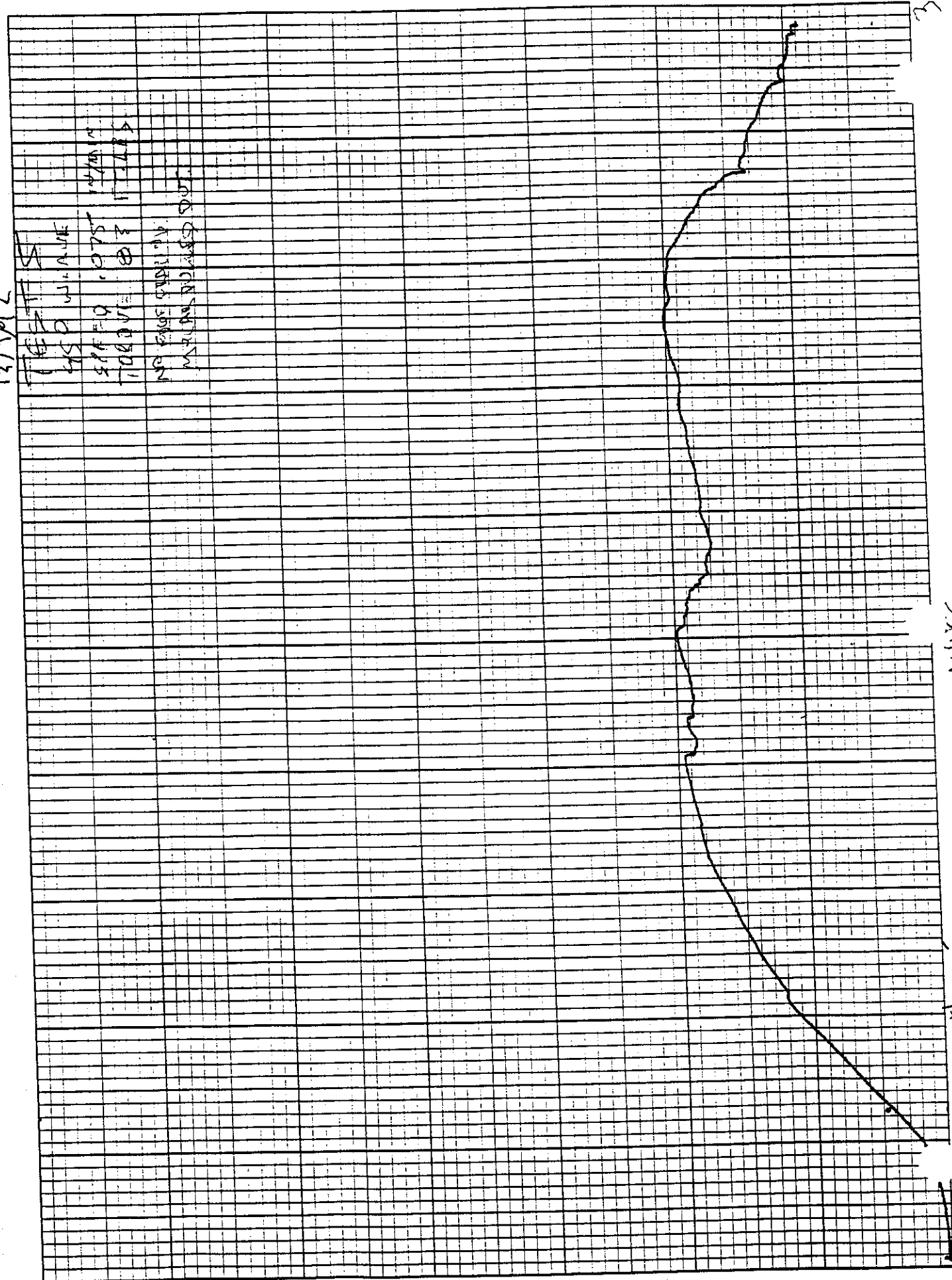


TEST # 4  
REGULAR SET JP  
REOUT OK 130 HBS  
SPEED 175 1440  
TDRIVE 179 FT LBS  
MAX FORCE 3900 LBS  
WEAVE 90°

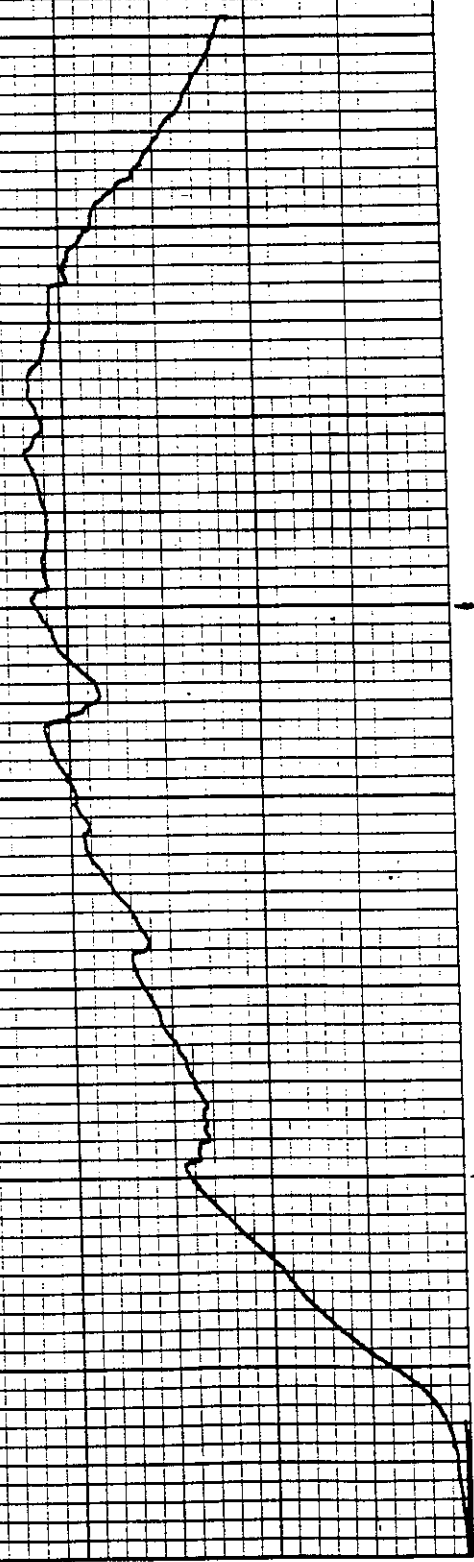


12/7/62

TEST S  
450 WILMIE  
SPR=0, 0.75- 14/10/10  
TODAY 03 11/11/62  
NO PAGE 5001.10  
METER 100.00 000



lost the  
way <sup>down</sup> the  
river  
of hell



NC. 1452

Test 1  
Tensile SS. Frills  
150 WEAVE  
5/16 200 10.25

24

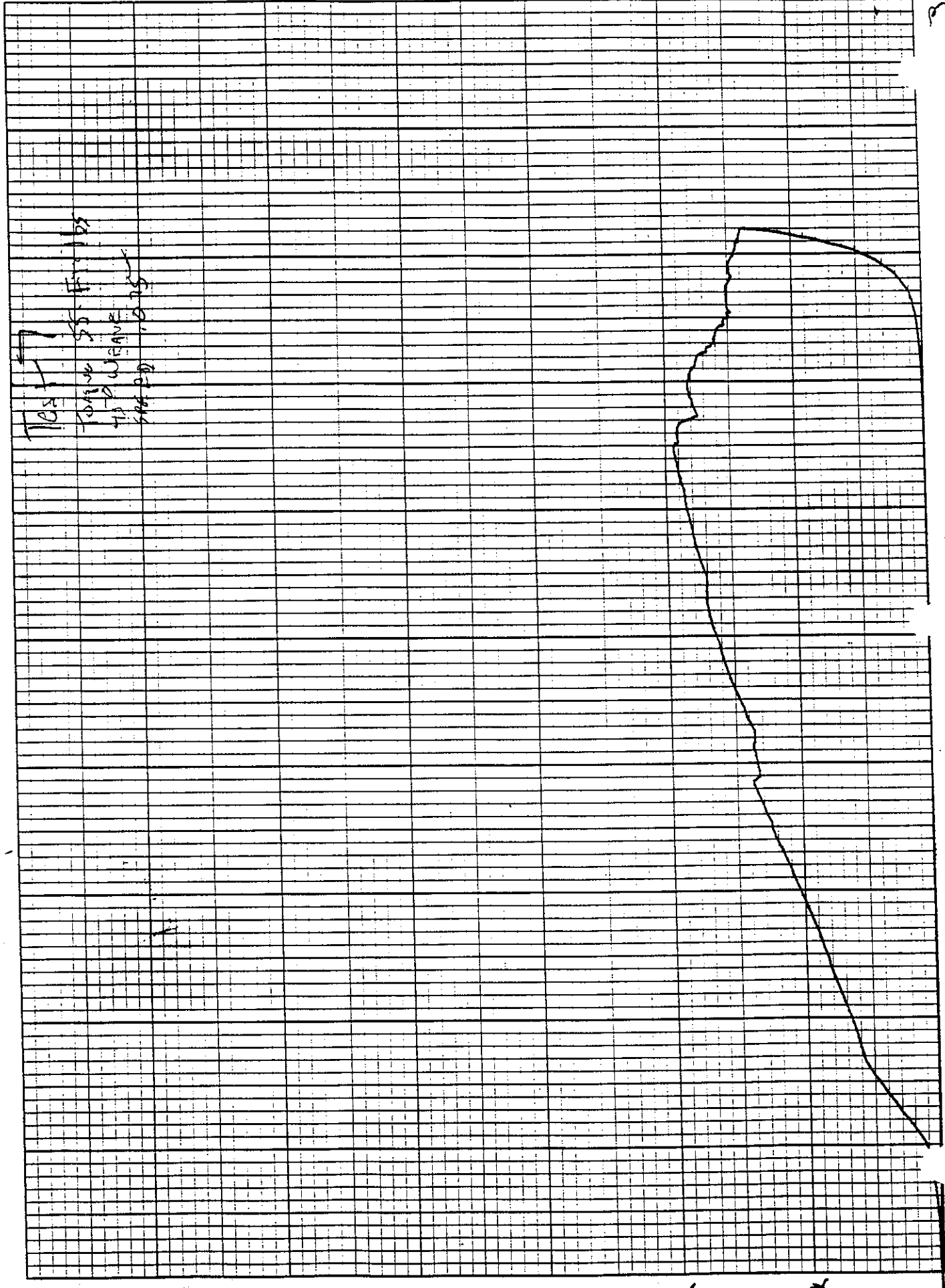
1K

2

3

5000 LBS

16.  
7



23

11

ADD WAVE

5/2/20

TopoQuest 11/15/11

$\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$

Math

Area

Perimeter

Volume

Surface Area

Probability

Statistics

Geometry

Algebra

Calculus

Trigonometry

Number Theory

Logic

Set Theory

Combinatorics

Graph Theory

Topology

Differential Equations

Integral Calculus

Linear Algebra

Matrix Theory

Group Theory

Ring Theory

Field Theory

Module Theory

Category Theory

Homological Algebra

K-Theory

String Theory

Quantum Mechanics

Relativity

Cosmology

Astrophysics

Particle Physics

Nuclear Physics

Atomic Physics

Molecular Physics

Optics

Acoustics

Thermodynamics

Statistical Mechanics

Classical Mechanics

Newtonian Mechanics

Lagrangian Mechanics

Hamiltonian Mechanics

Quantum Field Theory

Gauge Theory

Yang-Mills Theory

Electrodynamics

Electromagnetism

Gravitation

General Relativity

Special Relativity

Relativistic Quantum Mechanics

Quantum Chromodynamics

Quantum Electrodynamics

Weak Interactions

Strong Interactions

Standard Model

Supersymmetry

Extra Dimensions

Dark Matter

Dark Energy

Inflation

Big Bang

Cosmic Microwave Background

Galaxy Formation

Star Formation

Planetary Science

Exoplanets

Interstellar Medium

Neutron Stars

Black Holes

Hawking Radiation

Information Theory

Complexity Theory

Chaos Theory

Bifurcation Theory

Nonlinear Dynamics

Control Theory

Robotics

Artificial Intelligence

Machine Learning

Deep Learning

Reinforcement Learning

Evolutionary Algorithms

Genetic Algorithms

Ant Colony Optimization

Particle Swarm Optimization

Differential Evolution

Simulated Annealing

Tabu Search

Genetic Programming

Neural Networks

Fuzzy Logic

Expert Systems

Knowledge Representation

Automated Reasoning

Model Checking

Verification

Synthesis

Formal Verification

Hardware Description Languages

VLSI Design

Computer Architecture

Operating Systems

Database Systems

Networking

Internet

Wireless Communications

Mobile Computing

Cloud Computing

Data Mining

Text Mining

Image Processing

Speech Recognition

Handwriting Recognition

Facial Recognition

Biometrics

Security

Cryptography

Network Security

Malware Analysis

Reverse Engineering

Forensics

Incident Response

Disaster Recovery

Business Process Management

Supply Chain Management

Project Management

Human Resources Management

Marketing

Sales

Customer Relationship Management

Product Development

Quality Management

Lean Manufacturing

Six Sigma

Total Quality Management

Continuous Improvement

Change Management

Organizational Behavior

Leadership

Management Theory

Strategic Management

Entrepreneurship

Innovation

Research and Development

Technology Transfer

Commercialization

Patent Law

Intellectual Property

Trademark

Copyright

Patent Infringement

Trade Secret

Unfair Competition

Consumer Protection

Advertising

Promotion

Public Relations

Media Studies

Journalism

Writing

Editing

Publishing

Distribution

Retail

Wholesale

Manufacturing

Construction

Transportation

Logistics

Warehousing

Inventory Management

Procurement

Sourcing

Supplier Management

Vendor Selection

Contract Management

Legal Affairs

Compliance

Regulatory Affairs

Government Relations

Public Policy

Legislation

Lawmaking

Judiciary

Judicial System

Courts

Tribunals

Arbitration

Mediation

Conciliation

Restorative Justice

Victim Support

Witness Protection

Prison System

Corrections

Probation

Parole

Rehabilitation

Community Corrections

Drug Courts

Mental Health Courts

Family Courts

Youth Courts

Specialized Courts

Alternative Dispute Resolution

Dispute Resolution

Conflict Resolution

Peacekeeping

International Law

Human Rights

Environmental Law

Maritime Law

Air Law

Space Law

Energy Law

Telecommunications Law

Internet Law

Privacy Law

Data Protection

Electronic Privacy

Digital Rights

Cyberlaw

Online Privacy

Virtual Reality

Augmented Reality

Extended Reality

Metaverse

Blockchain

Cryptocurrency

Bitcoin

Ethereum

Smart Contracts

Distributed Ledger Technology

Decentralized Finance

DeFi

Non-Fungible Tokens

NFTs

Digital Art

Digital Collectibles

Digital Assets

Digital Identity

Digital Signature

Digital Seal

Digital Stamp

Digital Certificate

Digital Passport

Digital Visa

Digital License

Digital Permit

Digital Approval

Digital Consent

Digital Agreement

Digital Contract

Digital Deal

Digital Transaction

Digital Exchange

Digital Marketplace

Digital Storefront

Digital Shop

Digital Mall

Digital Bazaar

Digital Fair

Digital Market

Digital Plaza

Digital Square

Digital Park

Digital Garden

Digital Forest

Digital Ocean

Digital Sky

Digital Earth

Digital Universe

Digital Cosmos

Digital Galaxy

Digital Star

Digital Planet

Digital Moon

Digital Sun

Digital Fire

Digital Water

Digital Air

Digital Soil

Digital Rock

Digital Metal

Digital Wood

Digital Plant

Digital Animal

Digital Human

Digital Spirit

Digital Soul

Digital Mind

Digital Heart

Digital Brain

Digital Nerve

Digital Muscle

Digital Bone

Digital Skin

Digital Hair

Digital Nail

Digital Tooth

Digital Eye

Digital Ear

Digital Nose

Digital Mouth

Digital Tongue

Digital Throat

Digital Esophagus

Digital Stomach

Digital Intestine

Digital Liver

Digital Gallbladder

Digital Pancreas

Digital Spleen

Digital Lung

Digital Trachea

Digital Bronchus

Digital Alveoli

Digital Capillary

Digital Vein

Digital Artery

Digital Pulse

Digital Blood

Digital Plasma

Digital Red Blood Cell

Digital White Blood Cell

Digital Platelet

Digital Fibrinogen

Digital Hemoglobin

Digital Myoglobin

Digital Creatinine

Digital Urea

Digital Glucose

Digital Insulin

Digital Testosterone

Digital Estrogen

Digital Progesterone

Digital Cortisol

Digital Adrenaline

Digital Dopamine

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Digital Melatonin

Digital Histamine

Digital Acetylcholine

Digital GABA

Digital Glutamate

Digital Glycine

Digital Aspartate

Digital Glutamate

Digital Alanine

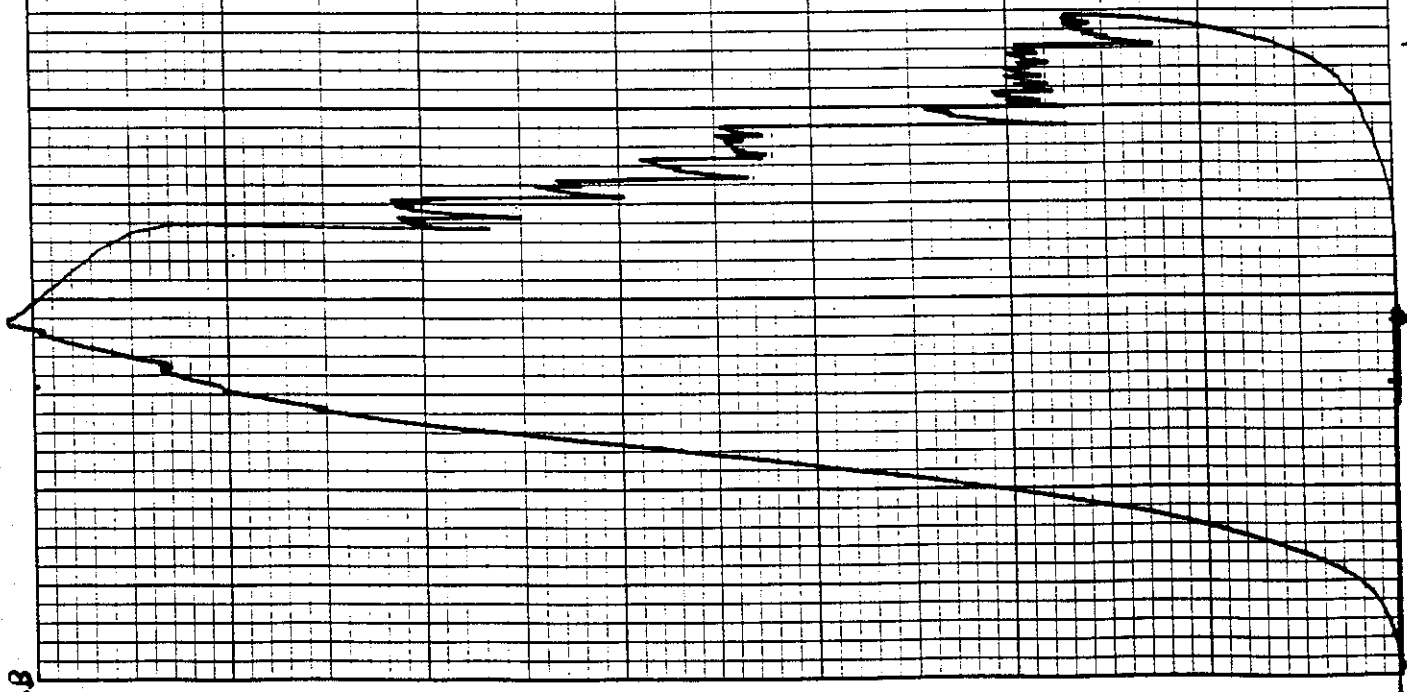
Digital Valine

Digital Leucine

Digital Isoleucine

Digital Phenylalanine

Digital Tyrosine</

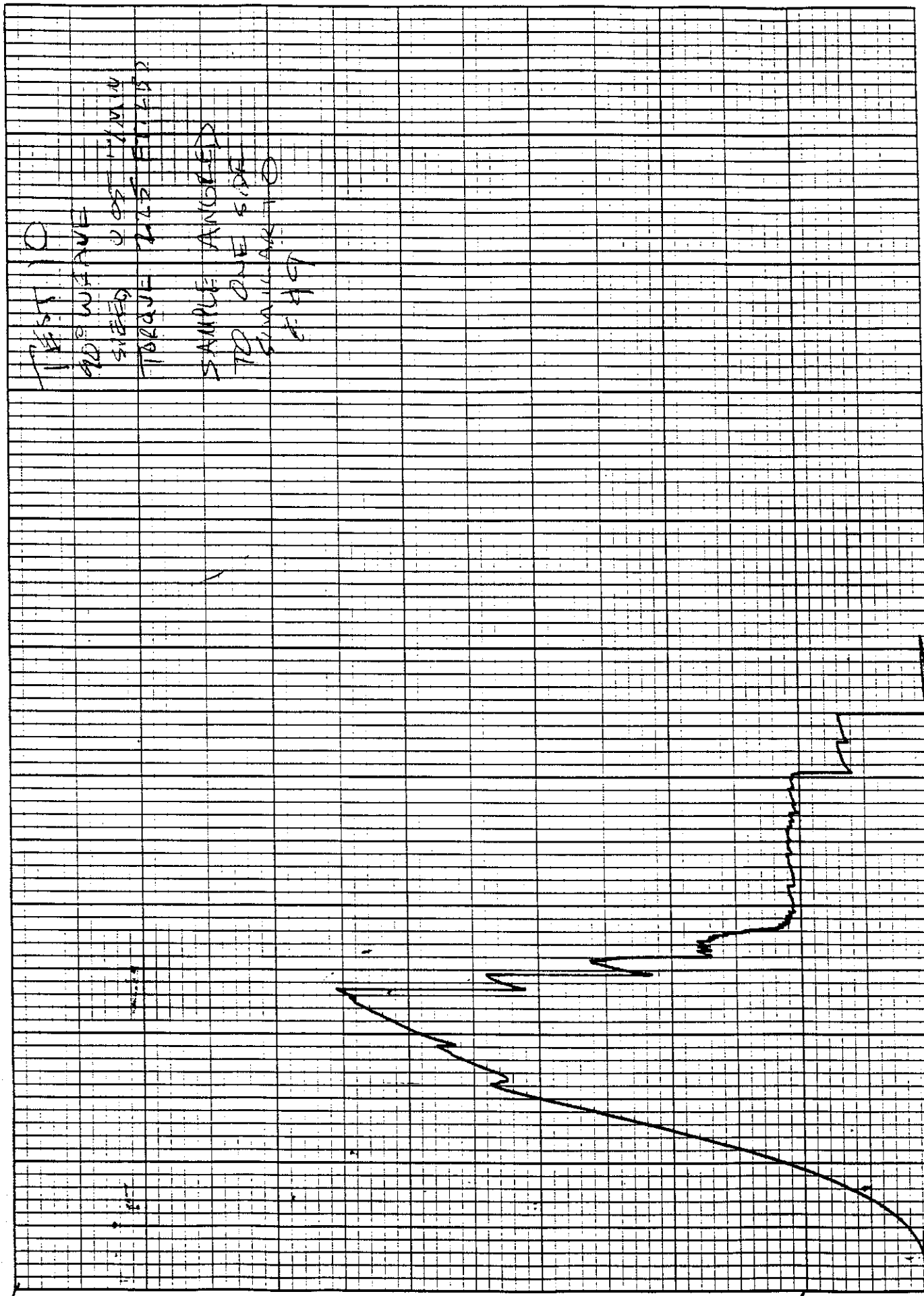


**K&E** 10 X 10 TO THE INCH • 7 X 10 INCHES  
KEUFFEL & ESSER CO. MADE IN U.S.A.

02050

two STRAPS  
1-4 KNOTS

225



TEST 10  
90° WAVE  
SPEED 0.05 MIN  
TORQUE 2.15 FT-LBS  
SAMPLE ANGLED  
TO ONE SIDE  
MARK 10  
F 49

TEST #11

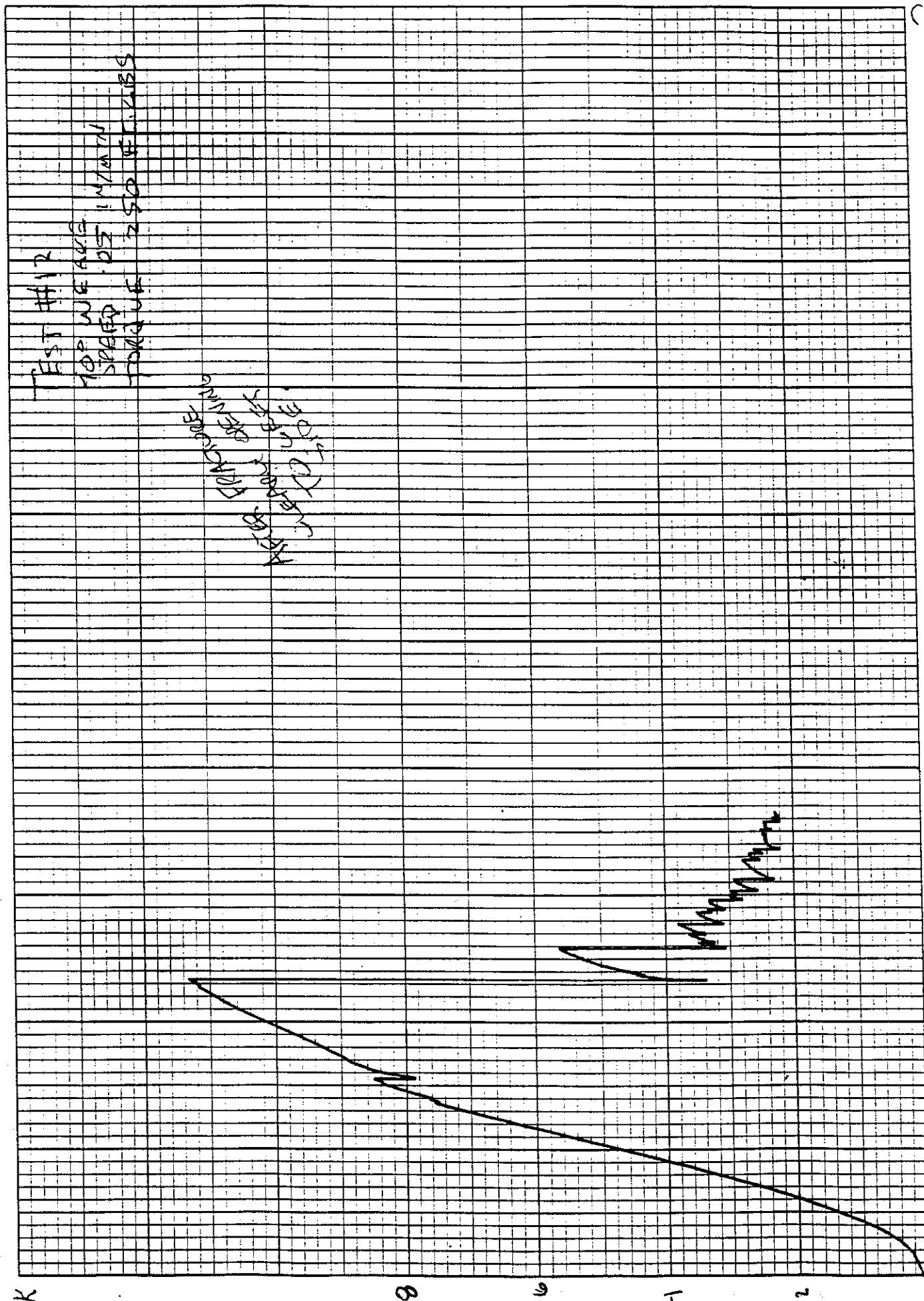
NO. WEAVE

SPEED 0:05.10/100 IN

TORQUE 167 FT LBS





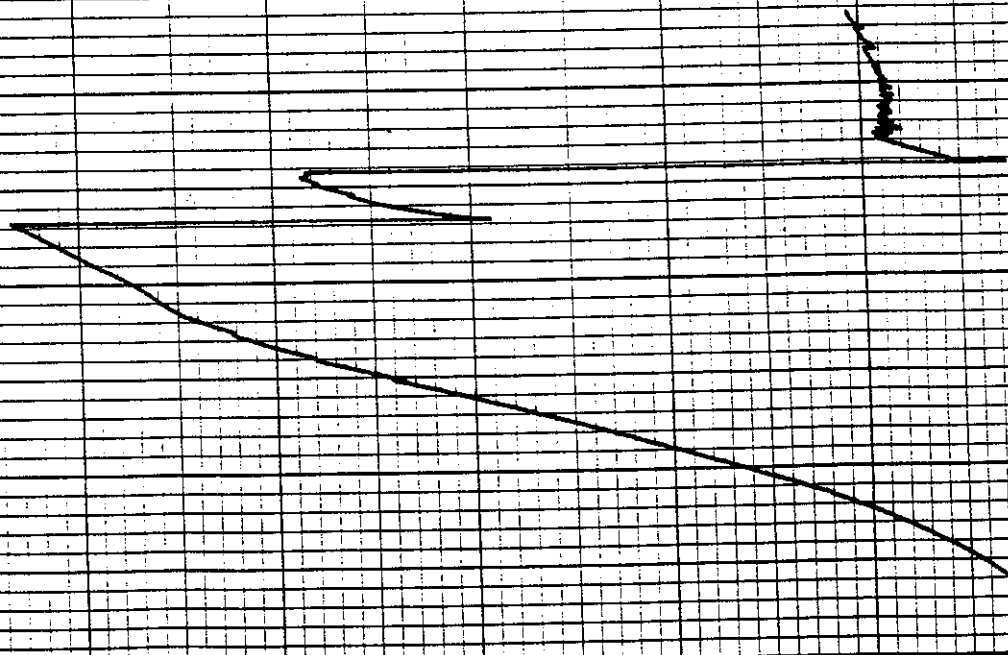


TEST 113

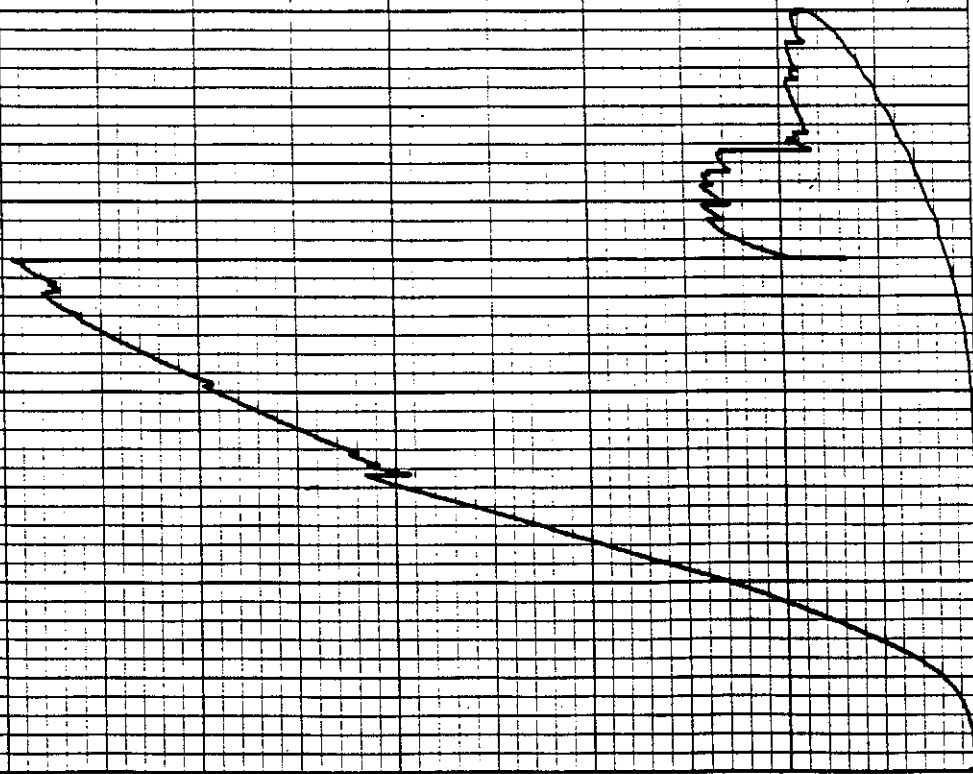
NO WEAVE

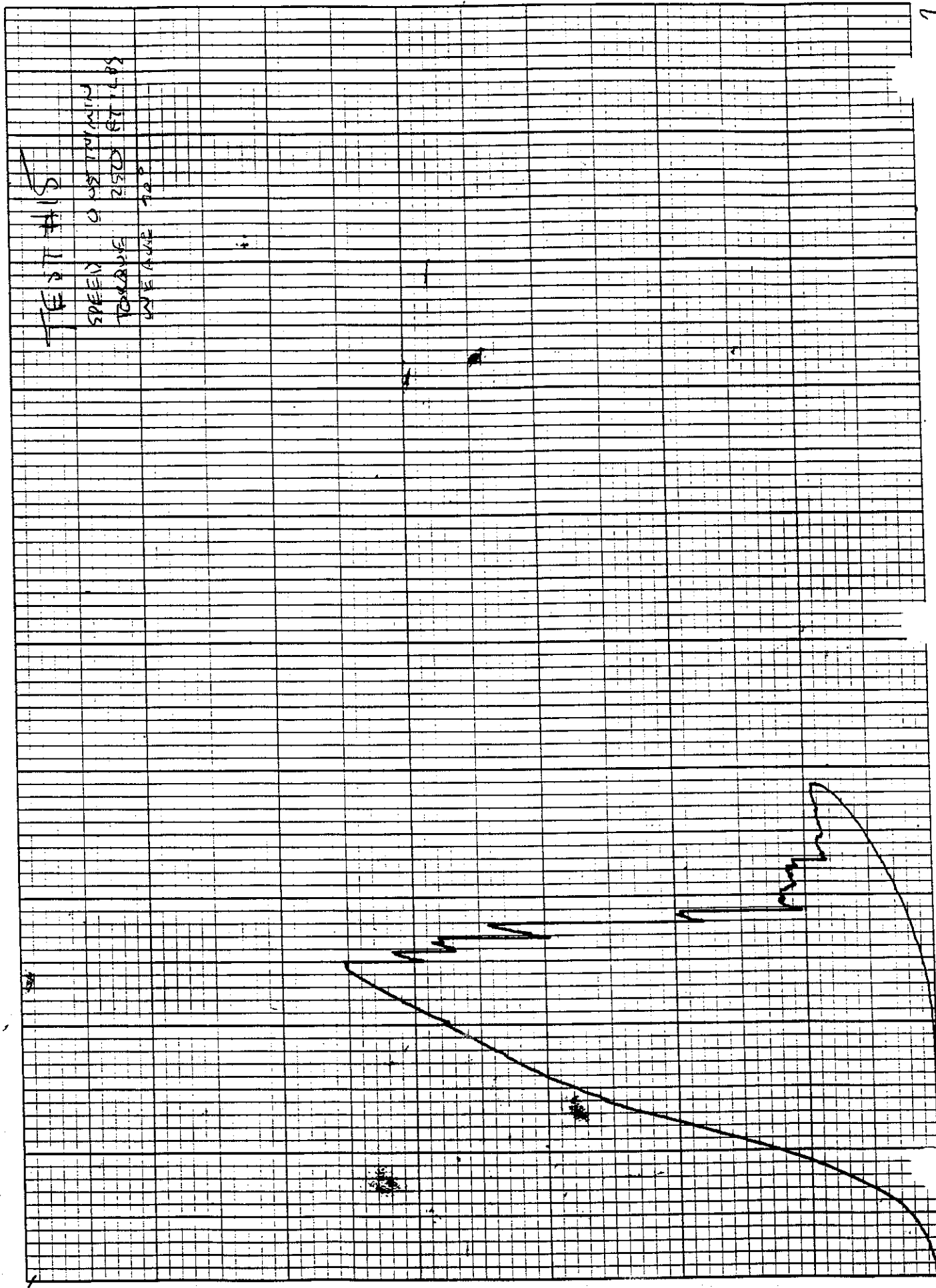
SPEED 0.45 IN/MIN

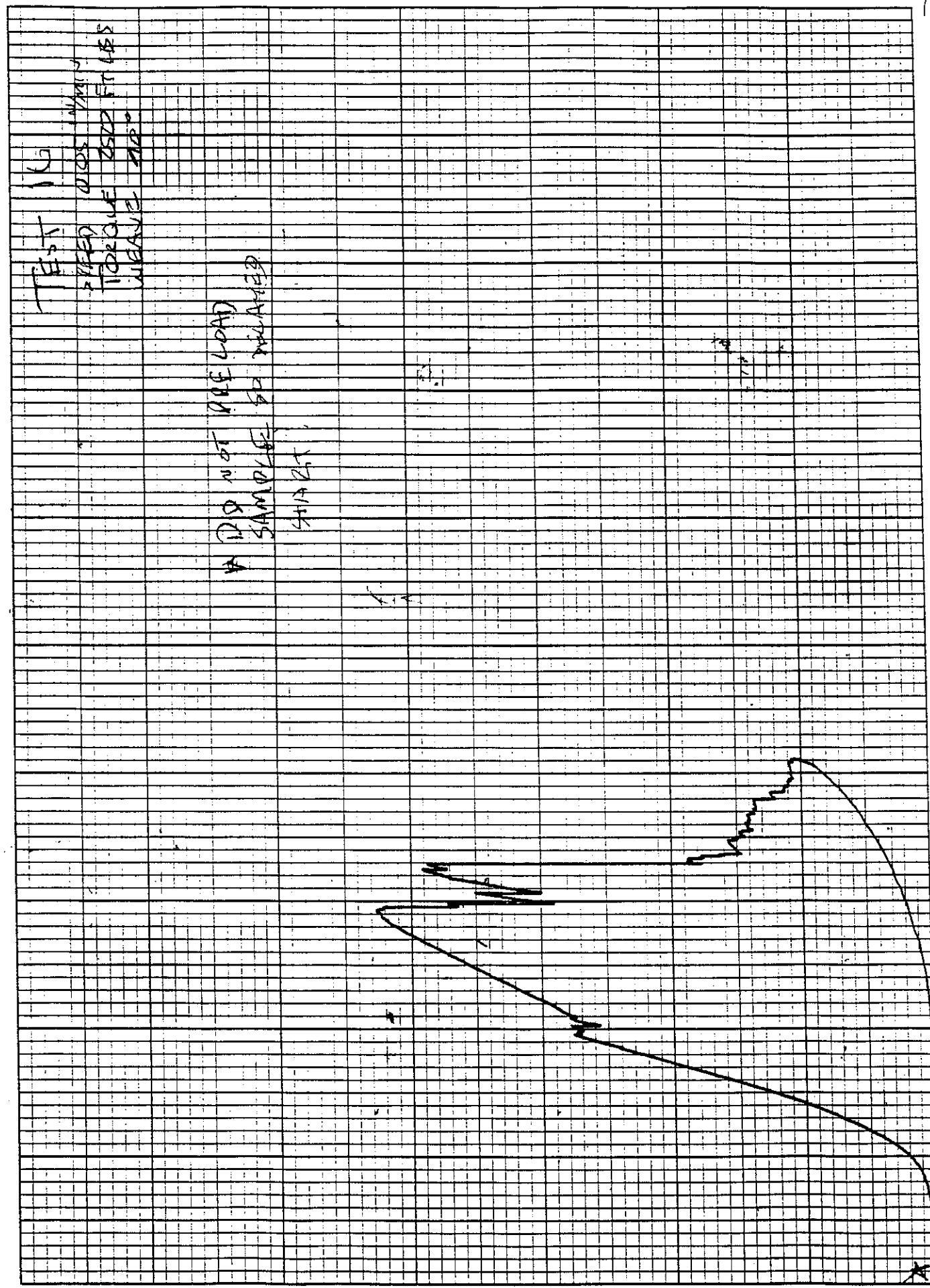
TORQUE 200 FT-LBS



TEST # 4  
SPEED 0.05 MIN  
90° WEAVE  
TORQUE 200 PF4RS







TEST # 17

SPEED 0.05

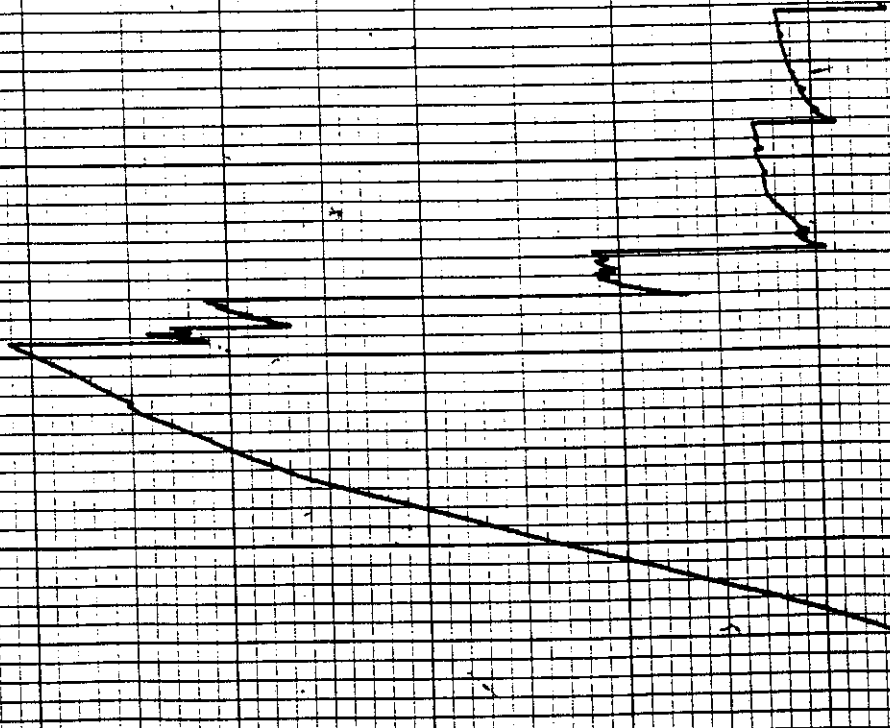
40° WEAVE

ROLLING CSO BTZDS

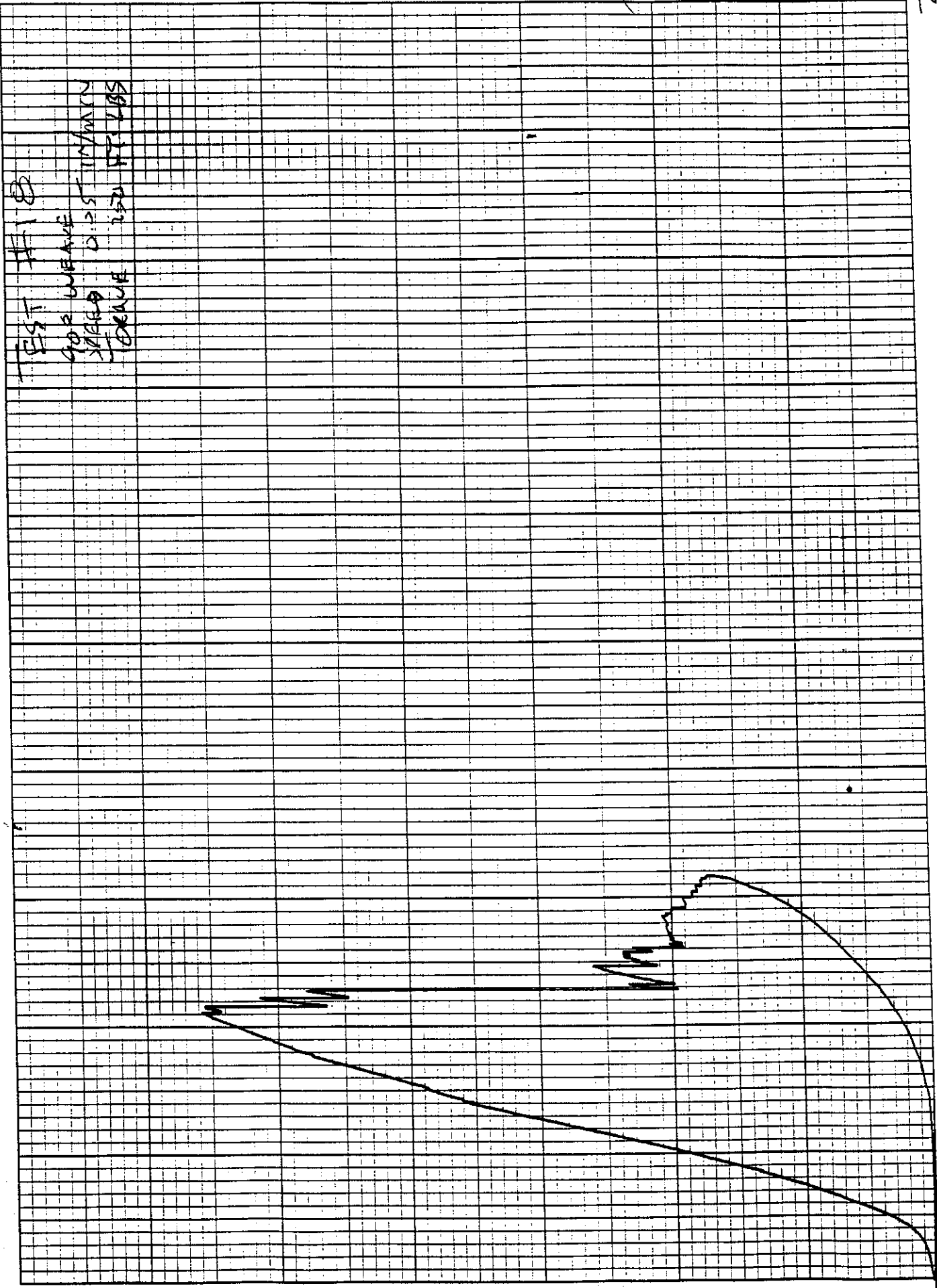
NEW BOLTS

USED FOR T-HD

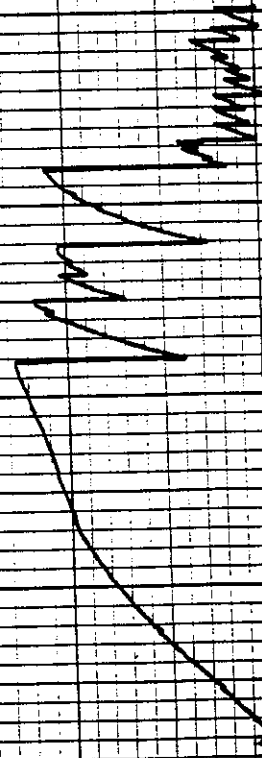
TEST



INCUBATION



TEST 19  
SPEED 0.05 IN/SEC  
WEIGHT 15.0  
TENSILE 250 F-165





TEST 20  
450 WEAVER  
TORQUE 1500 FT-LBS  
SPEED 3.0570 MIN

1000/1000

1951 #2

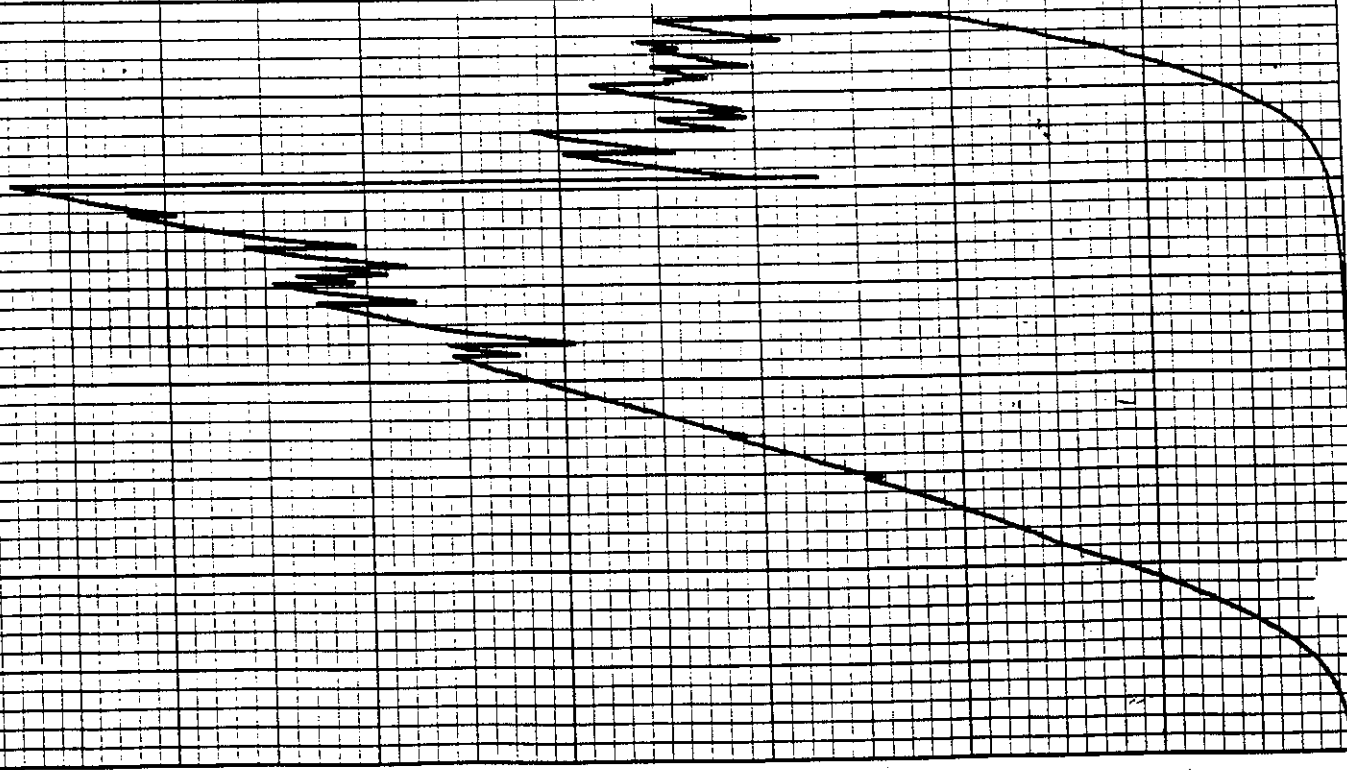
no album, the A

SOME TEXTS USED

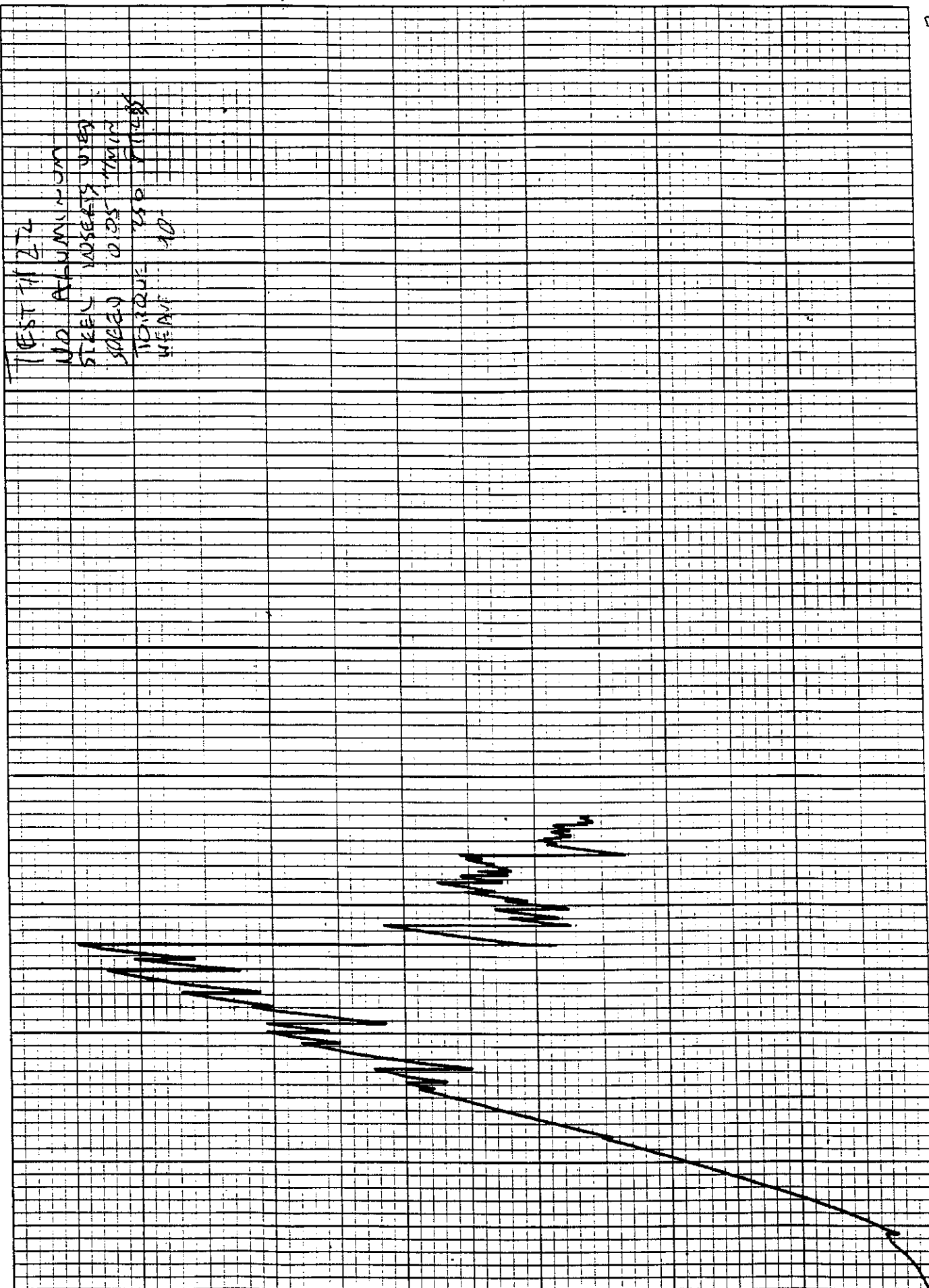
03-175  
865-965-965

WEAVER 900

2/17/12  
DSD  
DSD



30.



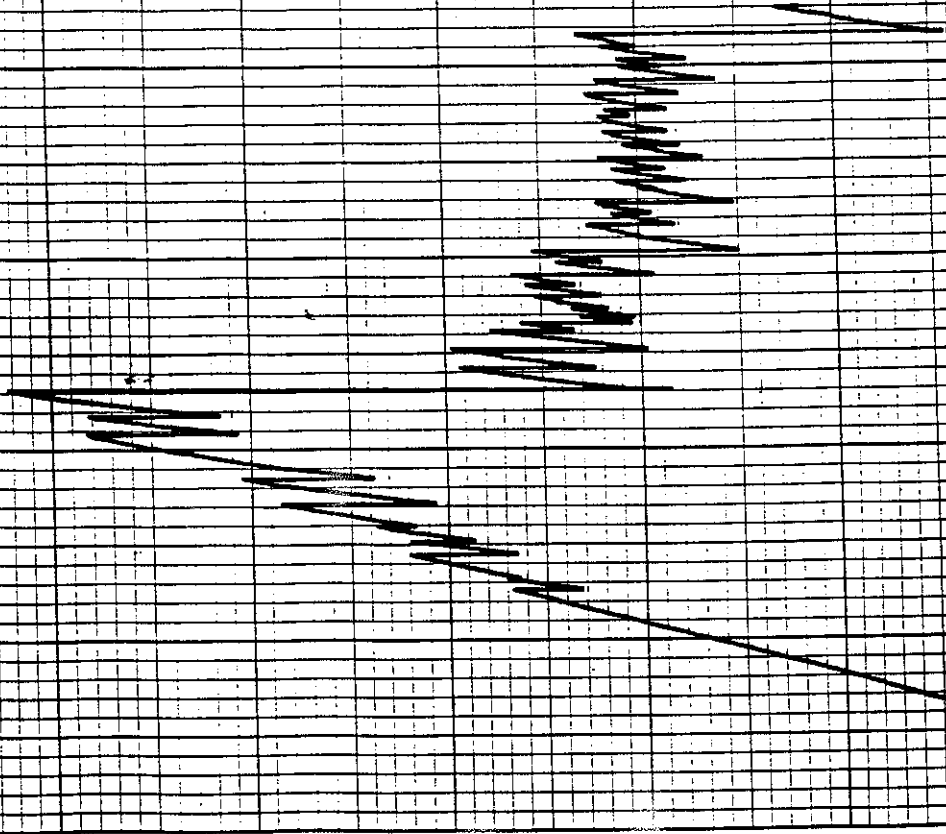
TEST 23

NO ALUMINUM

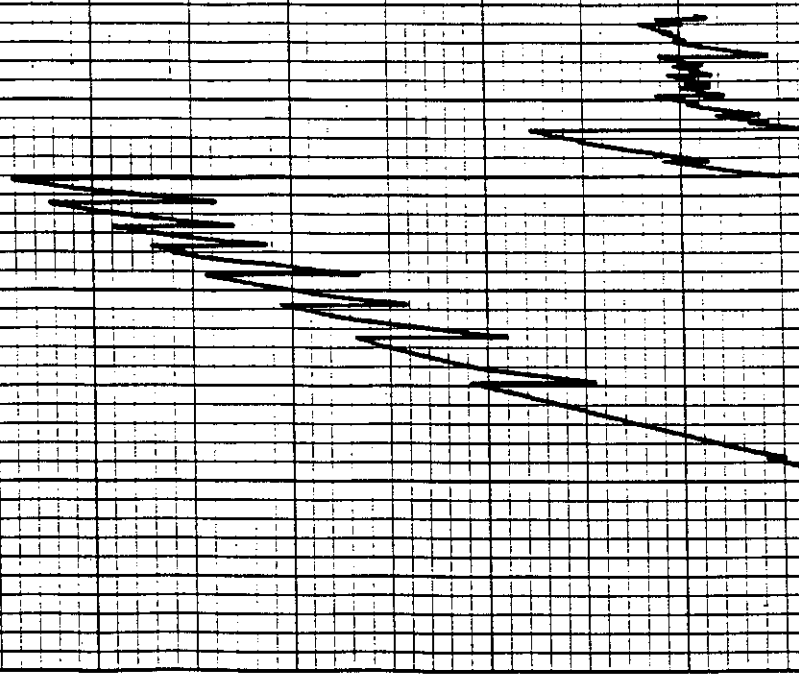
Torque 250 FT-LBS

STEEL DISC

WEAVE 40°



TEST 29  
NO ALUMINUM  
TORQUE 250 FT/LB  
SPEED 0.05 IN/MIN  
WRAVE 90°



11

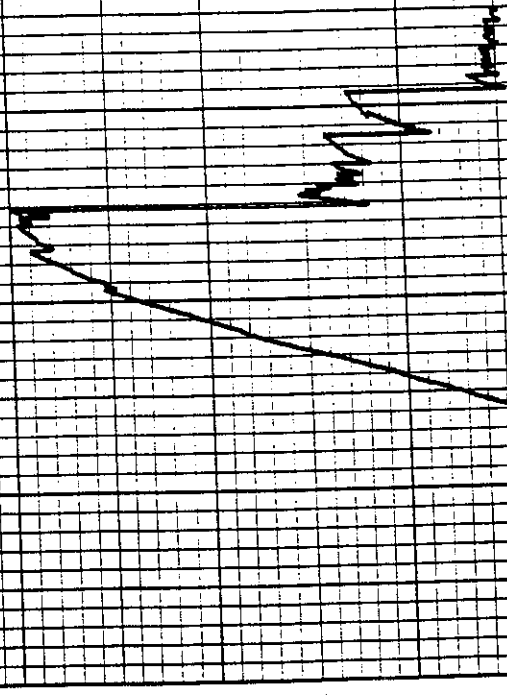
TEST #25

ALL SPACERS - NEW

TORQUE 150 FT-LBS

WEAR 41"

SCREEN 200 MESH



TEST #26

AL SPACER

TURBINE 200 PSI

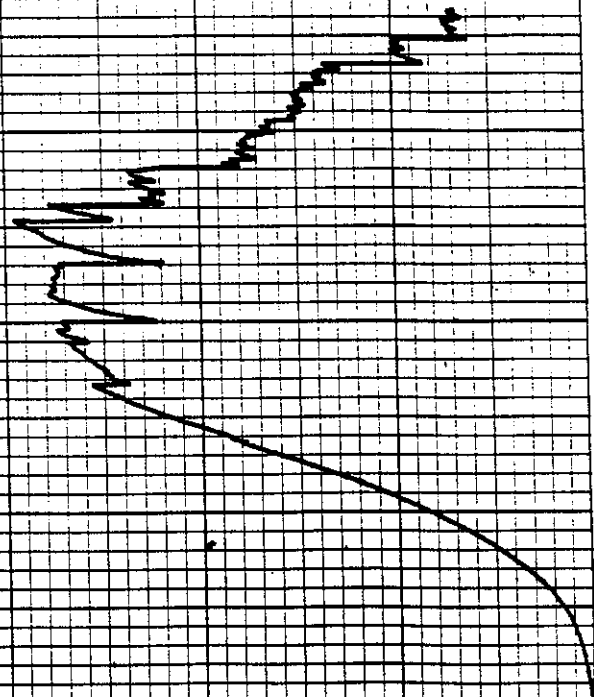
SPEED 2000 RPM

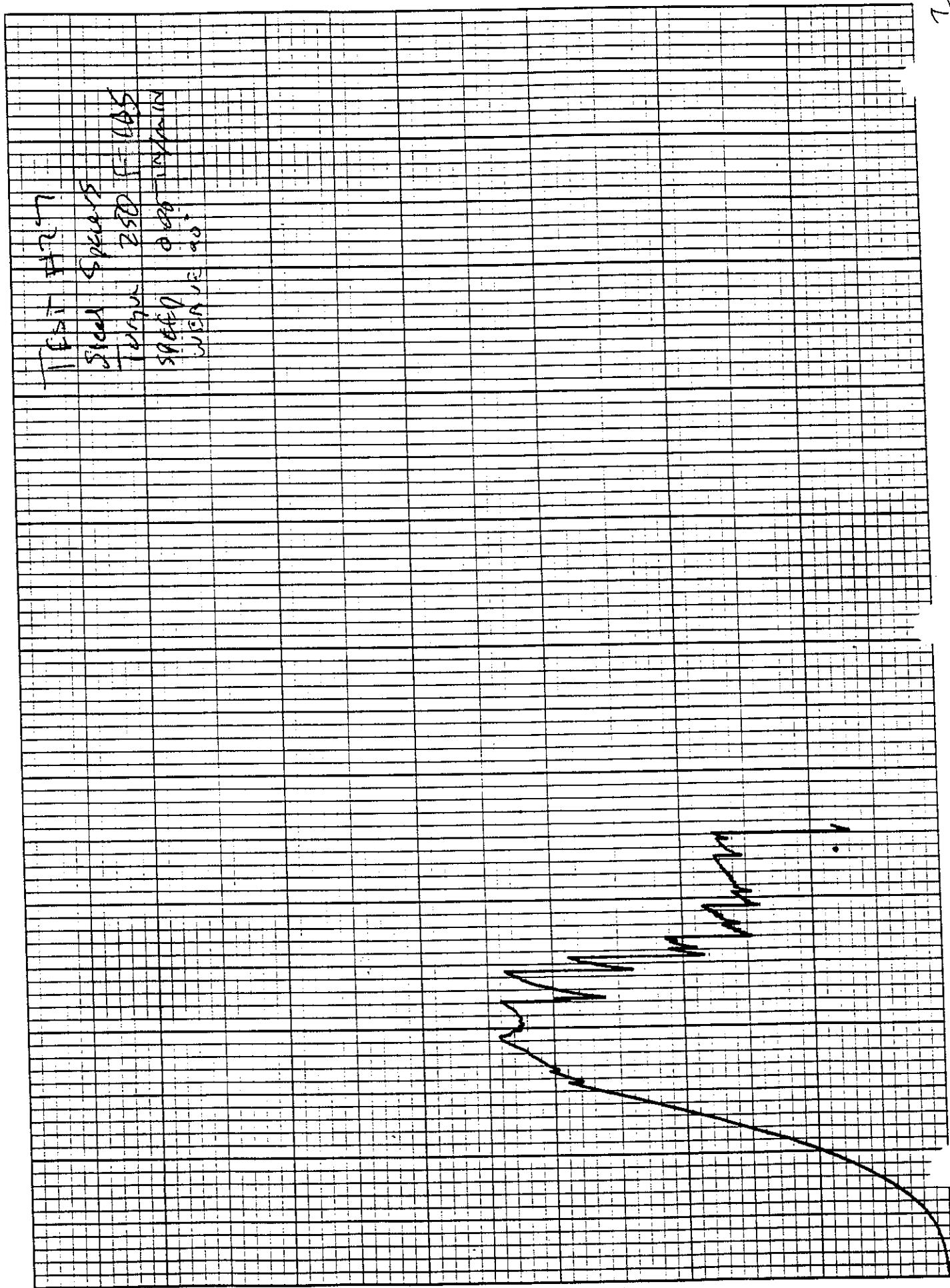
WEIGHT 400

Exhaust Spacer on 1

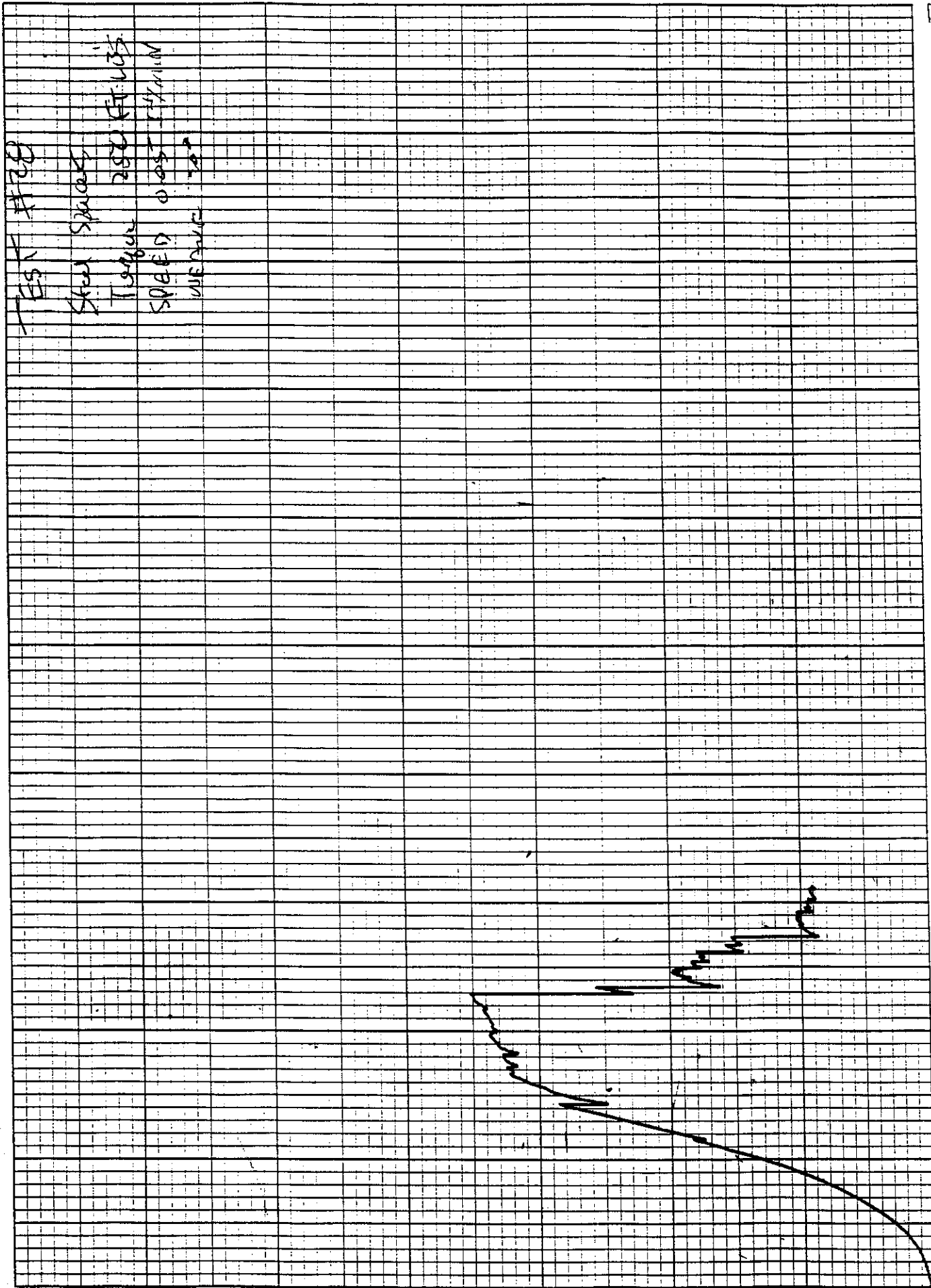
Bolt Accidental

probably affected results









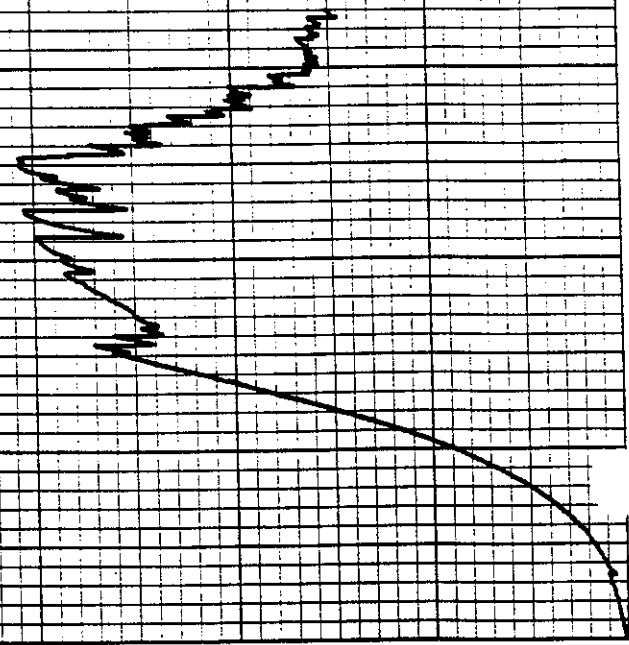
TEST 29

USED AL SPARKERS

SPEED 2250 RPM

TORQUE 2500 FT-LBS

WESUE 400



Kevlar Window Tests Part II  
KTev 1.8m Window

Frederick Renken

7/23/93

FNAL RD/MSD Mechanical Support Group

## ABSTRACT:

A second series of tests was performed for the KTev 1.8m kevlar reinforced vacuum window. These tests were done to verify the results of previous tests (December 1992) and to find the effects of added epoxy and a different kevlar fabric manufacturer. The tests indicate that the bulkhead design and construction is sufficient to handle three times the operating pressure exerted during operating vacuum conditions. The addition of the epoxy dramatically improved the bulkhead performance and no significant differences in kevlar fabric could be noted. Some concerns remain over the validity of these tests but the window should perform at least as well or better than the tests indicate.

## INTRODUCTION:

KTev, the new fixed target experiment at Fermilab, uses a large kevlar fabric reinforced mylar vacuum window. To verify the window meets safety and performance requirements a series of tests were performed using a clamping fixture prepared for a tensile test. The fixture was designed to simulate the bulkhead for a tension load. The results of these tests provided a bolt torque at which the bulkhead would be able to maintain a vacuum seal without damaging the mylar window material. The tests also verified which bulkhead construction and configuration would perform best. [RENK 1992] [SZYM 1993]

After the completion of tests in December 1992 it became necessary to perform another series of tests. These tests differed from the previous tests by the addition of epoxy to the test samples and a change in kevlar fabric manufacturer. The epoxy, used in all vacuum windows on site, was not used in previous tests because the cure requires 24 hours. This amount of time was neither available nor practical for the earlier tests. The second tests investigated the effects of the epoxy on both the load at first slip and the load at failure. A new fabric manufacturer was necessary because the old one could not supply a single sheet to cover the 1.8m window. Testing was performed in two orientations because the new fabric did not contain the same number of threads per inch in both weave directions. Finally, a new part was required for the Instron testing machine to safely test to the higher loads expected. Everything else, including bolt torque of 250 ft lbs and the clamping fixtures using aluminum o-rings, was the same for the second tests.

A:

r Test Data  
Renken

Sample	Orientation (vertical threads/inch)	First Slip (kips)	Max Load (kips)	Notes
	35	12.8	13.4	
	35	12.9	13.05	Test Curve Lost/Computer Failure
	35	11.9	11.99	Unusual Fail Pattern
	35	12.5	13.33	
	35	11.9	11.96	
	Average:	12.4	12.746	
	Deviation:	0.480	0.716	
	34	14.5	14.51	Almost Complete Fracture
	34	13.1	13.1	Sample made with "Tension"
	34	15.25	15.25	
	34	13.9	13.96	
	Average:	14.188	14.205	
	Deviation:	0.911	0.907	
S:	Average:	13.194	13.394	Desired is 13.094
	Deviation:	1.146	1.075	

ES:

ation signifies the number of threads per inch sustaining the load or perpendicular to the  
ing fixtures. When one is looking at the sample, during the test, this is the number of  
is running vertically. The kevlar fabric is supplied with 35 threads per inch in one direction  
n through 34 threads perpendicular.

desired load to sustain was calculated from an ANSYS analysis of the window [SZYM  
]. These calculations determined the load along a section of the bulkhead the same length  
test sample for both vacuum conditions and for a safety factor of three. (Attached)

sts were performed at a crosshead speed of 0.05 inches per minute complying with ASME  
e testing standards.

## DISCUSSION OF DATA AND OBSERVATIONS:

Fraying was clearly evident on all samples. It was more prevalent in samples that fractured at lower values, especially around the bolt holes and epoxy region, . The test samples would fray along their edges during the entire test until failure. Fraying was also more significant on the samples with more threads in the pull direction. Fraying will not occur on the actual window because there are no free edges from which it can begin.

Effects of handling the samples during transportation and loading are indeterminate. The samples were prepared at Meson Assembly Building and then transported to the testing machine in the village. Since the testing clamps were somewhat heavy, loading samples into the machine was awkward and could have introduced failure points. Attempts to verify or control any effects were unsuccessful. Clearly the actual window will suffer no ill effects from handling and excessive transportation.

The data range is very high as indicated by the standard deviation. A high deviation leads to concerns over the validity of the tests. Engineering design and experience with existing windows should be considered along with these results. Furthermore, tests of the actual window will be the most accurate indicator of window performance.

The aluminum gaskets sustained similar deformation to previous tests. [RENK 1992]

Elongation of test samples approximately the same as previous tests. [RENK 1992]

Mylar remained undamaged, but reflected indentations from the aluminum o-ring.

## CONCLUSIONS:

The 1.8m window should be able to sustain a 45 psig load. This is a safety factor of three over the operating conditions of the window (14.7 psia on vacuum). As attached calculations show, the force exerted in the x direction at 45 psig is 13,094 lbf which is below both the average first slip and failure values of 13194 lbf and 13394 lbf respectively.

The fabric appears to be stronger in the direction with fewer threads per inch. This is probably due to fraying which was more evident in the first tests performed with 35 threads per inch sustaining the load. Without fraying the fabric is most likely the same in any direction. The actual window, being circular and enclosed, will not have any fraying and so will be able to sustain higher loads than these tests indicate. Otherwise no differences in kevlar manufacturers can be determined from this test.

Failure patterns indicate uneven load distribution on the sample or the presence of weaker possibly damaged points. It was impossible to test distribution with the apparatus despite attempts to create an even load throughout a preloaded test sample (kev7). To construct the actual window, a plywood frame will be used to apply tension to the kevlar cloth to evenly and efficiently distribute it across the bulkhead. This was also done on the four foot window previously constructed.

The use of epoxy on the test samples dramatically increased the load at which first slip occurred. Without the epoxy, the average first slip occurred at 7062 lbf. The final failure value was also increased by the use of the epoxy. This is shown by the increase from 10670 lbf, without the epoxy, to 13394 with the epoxy. Additional epoxy placed around the bolt holes, as was done on previous windows, may continue to improve load values but not significantly.



## REFERENCES:

- [RENK 1992] Renken, Frederick. "Kevlar Window Tests" 12/23/93 unpublished, submitted to A. Szymulanski and J. Kilmer.
- [SZYM 1993] Szymulanski, Andrew. "The 48 Inch Vacuum Window Component Inspection and its Impact on 1.8m Window Analysis." unpublished, a memo to J. Misek

## LOAD CALCULATIONS FOR TEST CLAMPING FIXTURE:

A. Szymulanski 12/18/93

ANSYS: At 45 psig (Safety factor of 3)

$T_x = 296280$  lbf: see Figure 1.

$T_x$  per linear inch of the circumference:

$$T_{x_i} = \frac{296280}{\pi(71)} = 1328.2 \text{ lb}$$

For a 9.858 inch wide fixture:

$$T_x = 13094$$

ANSYS: At 14.7 psia (vacuum operating conditions)

$T_x = 154880$  lbf.

$T_x$  per linear inch of the circumference:

$$T_{x_i} = \frac{154880}{\pi(71)} = 694.36$$

For 9.858 wide fixture:

$$T_x = 6845 \text{ lbf}$$

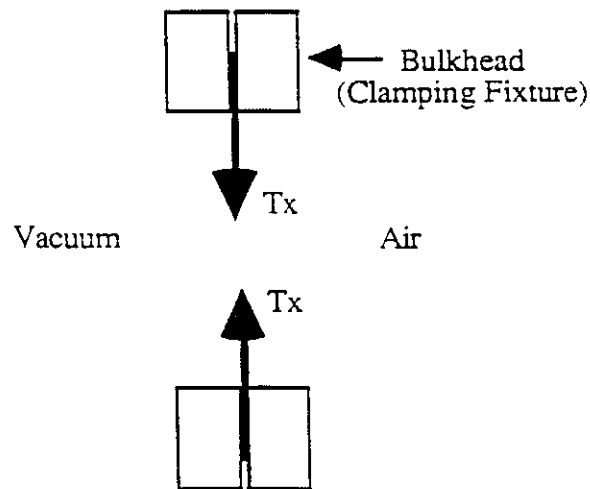
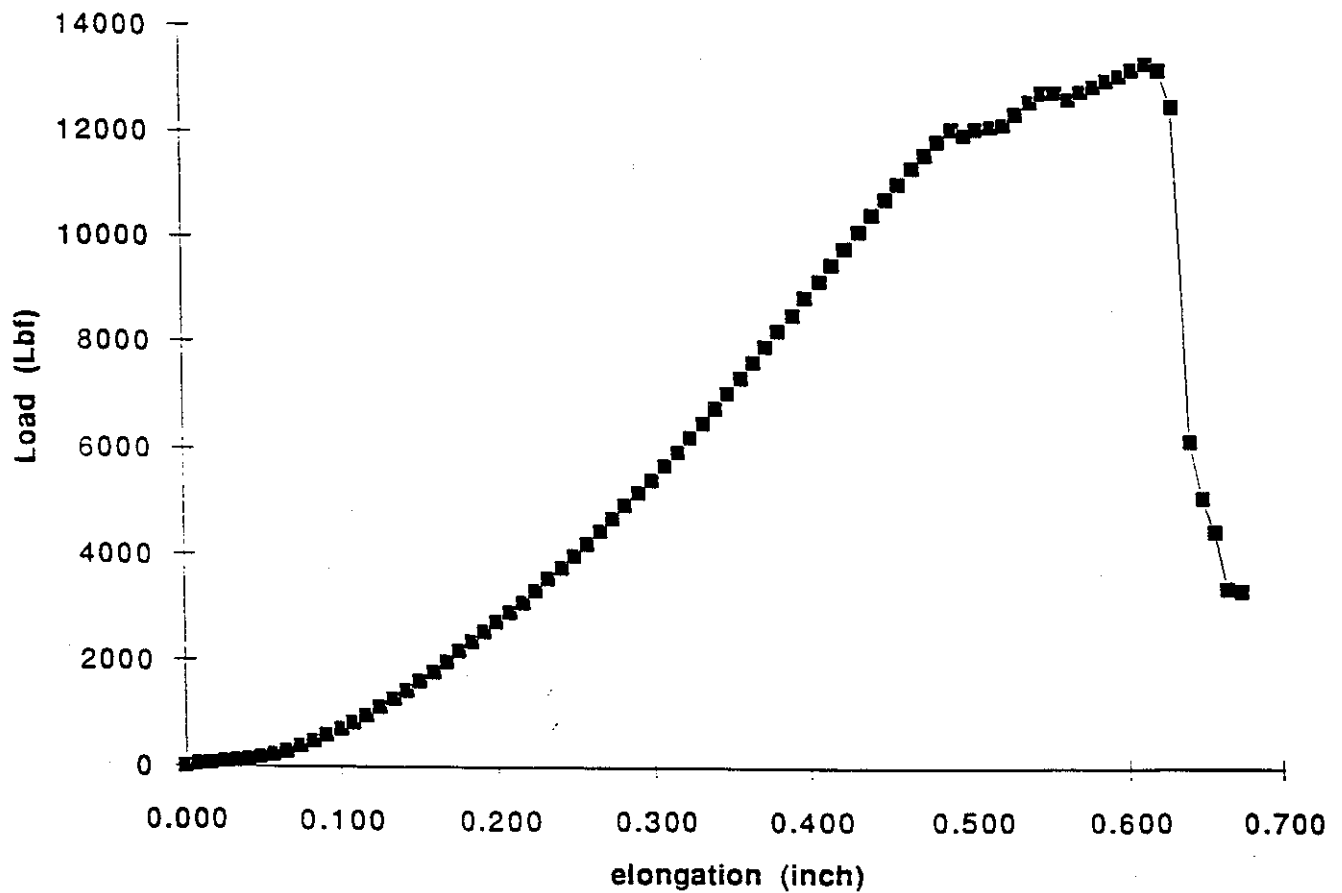


Figure 1: Cross Section of Bulkhead with force  $T_x$  exerted by fabric.

Kev1.6/30/93

	Fred Renken			
	30-Jun-93			
	Kevlar Test 1			
	Parallel count: 34			
	Perpendicular count: 35			
	Maximum Load 13.4 Kips			
	First Slip 12.8 kips			
	Standard Const—250 Ft·Lbs Torque			

Kev1 Test Curve

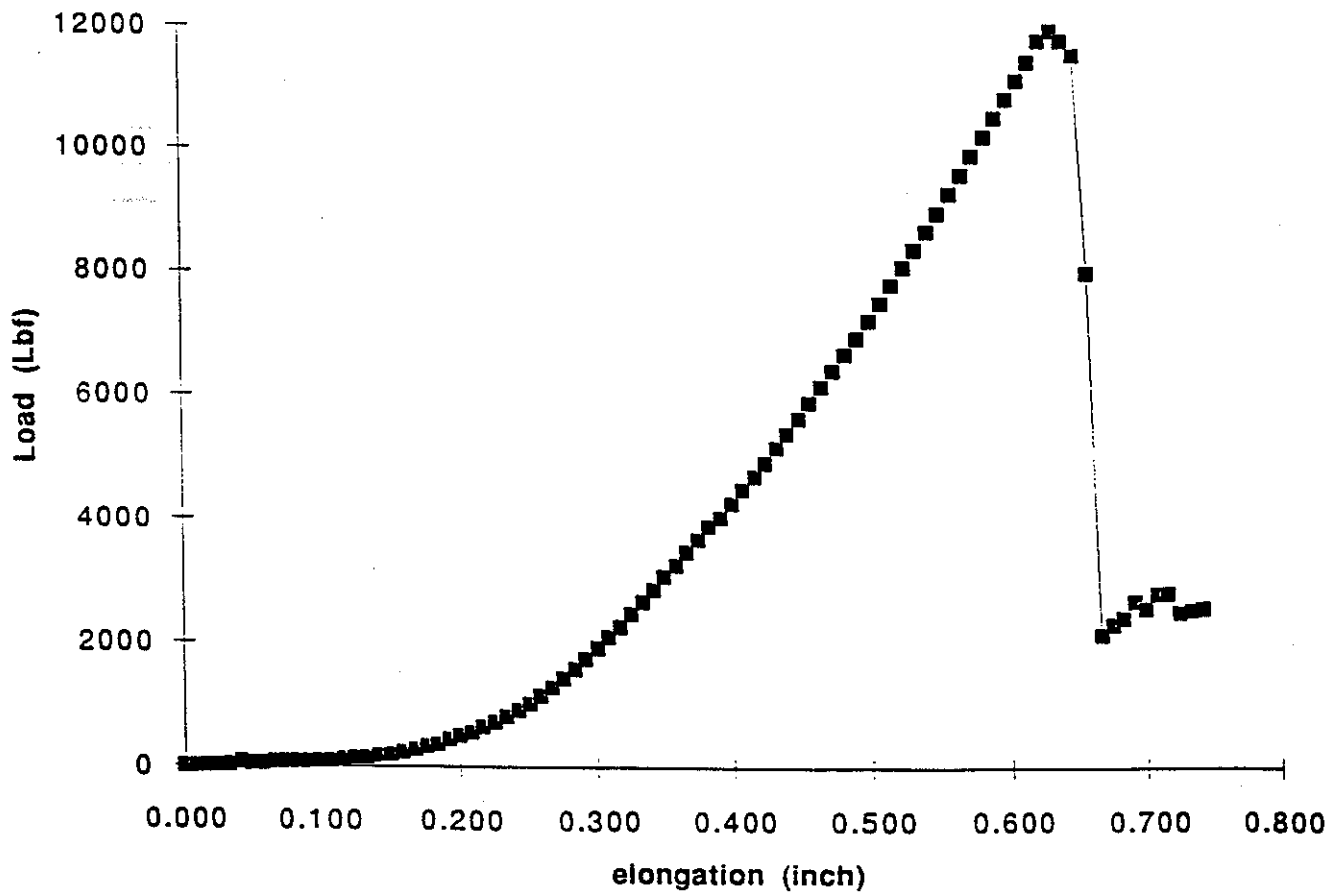


[illegible][illegible]

Kev3.7/6/93

Fred Renken				
6-Jul-93				
Kevlar Test 3				
Parallel count: 34	Orientation to test fixture			
Perpendicular count: 35				
Maximum Load 11.99 Kips				
First Slip 11.9 kips				
Standard Const—250 Ft•Lbs Torque				

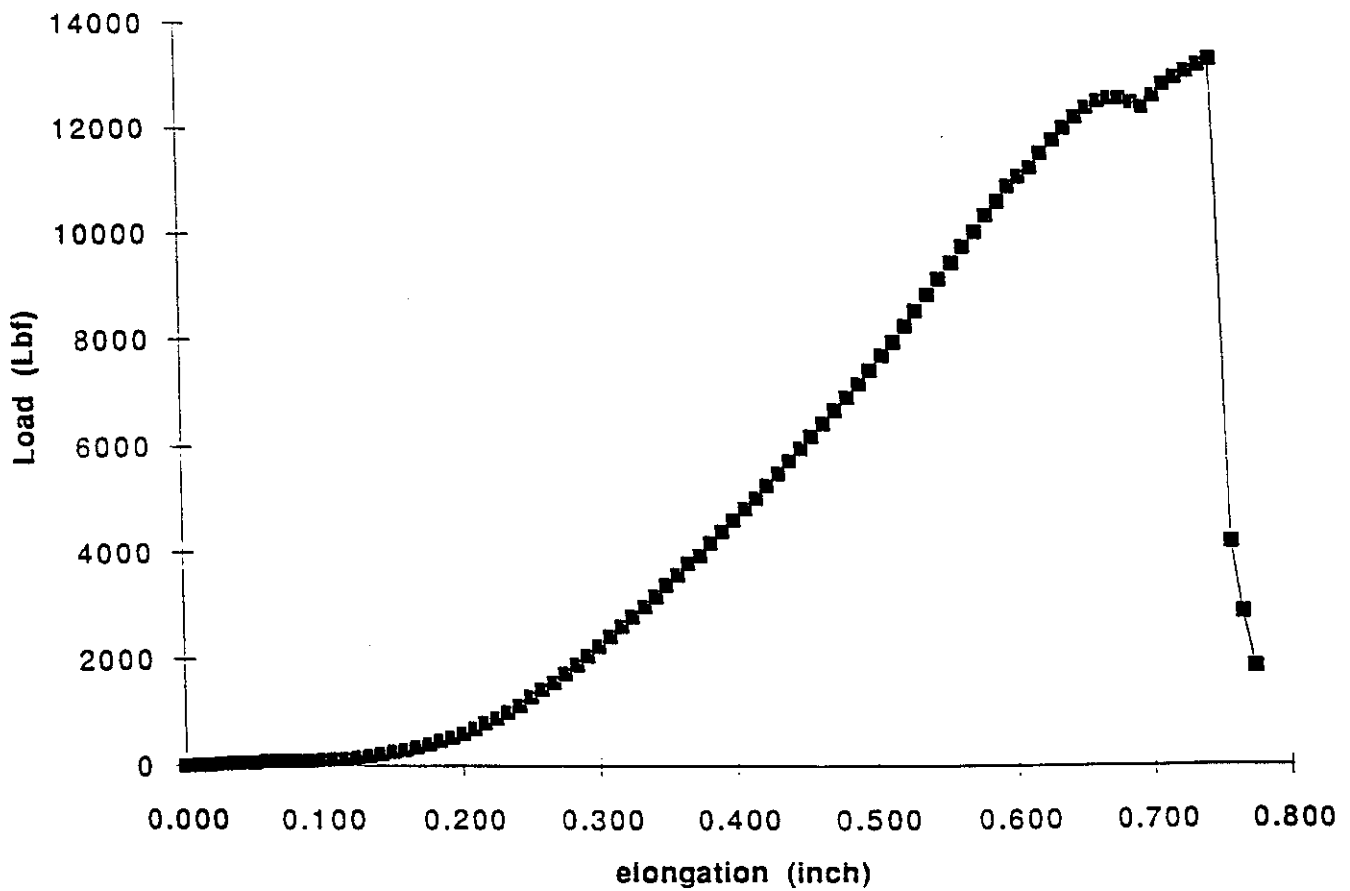
Kev3 Test Curve



Kev4.7/9/93

ion column					
	Fred Renken				
	9-Jul-93				
	Kevlar Test 4				
	Parallel count: 34				
	Perpendicular count: 35				
	Maximum Load 13.33 Kips				
	First Slip 12.5 kips				
	Standard Const—250 Ft•Lbs Torque				

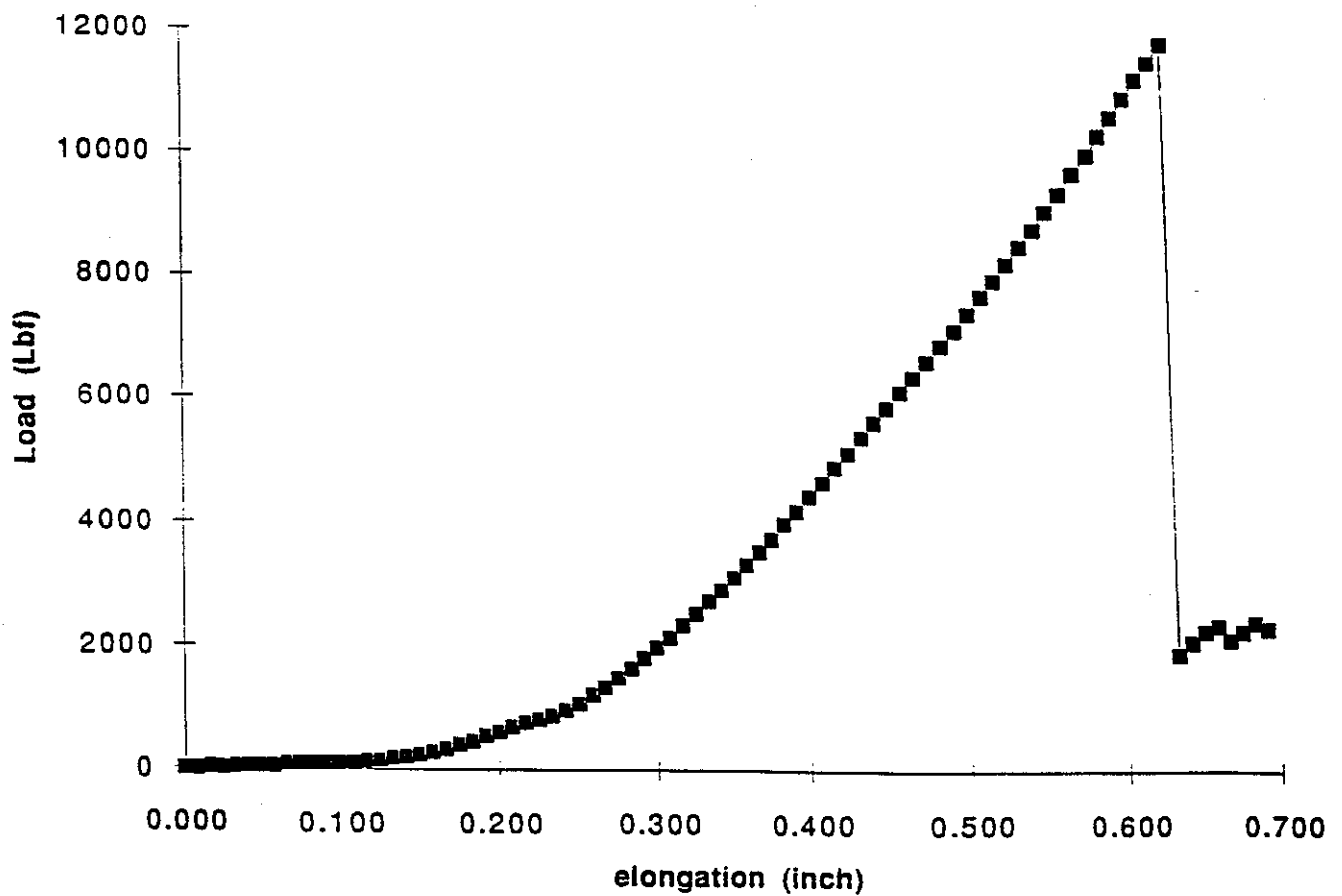
Kev4 Test Curve



Kev5.7/12/93

	Fred Renken				
	12-Jul-93				
	Kevlar Test 5				
	Parallel count: 34				
	Perpendicular count: 35				
	Maximum Load 11.96 Kips				
	First Slip 11.9 kips				
	Standard Const—250 Ft•Lbs Torque				

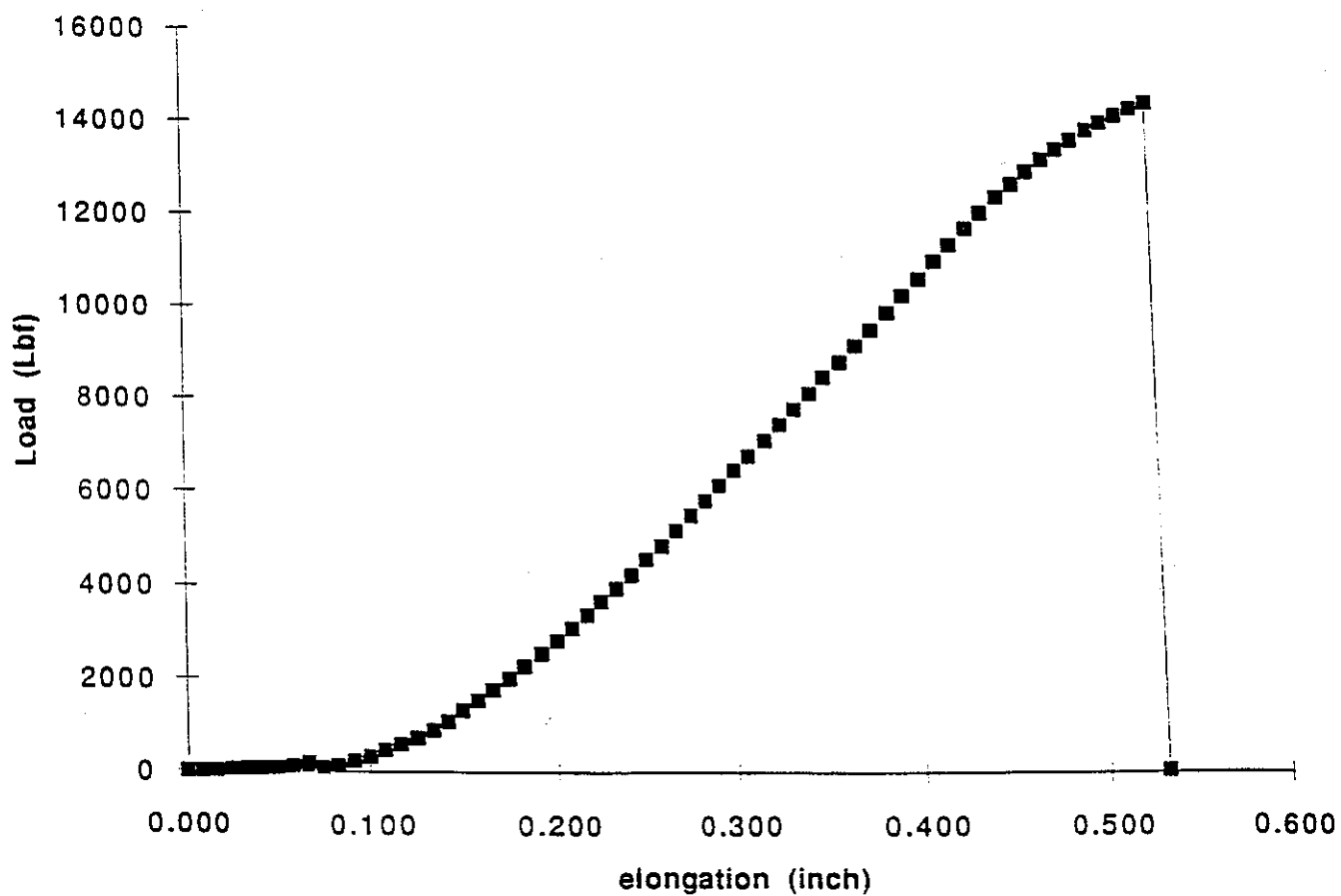
Kev5 Test Curve



Kev6.7/14/93

	Fred Renken				
	14-Jul-93				
	Kevlar Test 6				
	Parallel count: 35				
	Perpendicular count: 34				
	Maximum Load 14.51 Kips				
	First Slip 14.5 kips				
	Standard Const—250 Ft•Lbs Torque				

Kev6 Test Curve

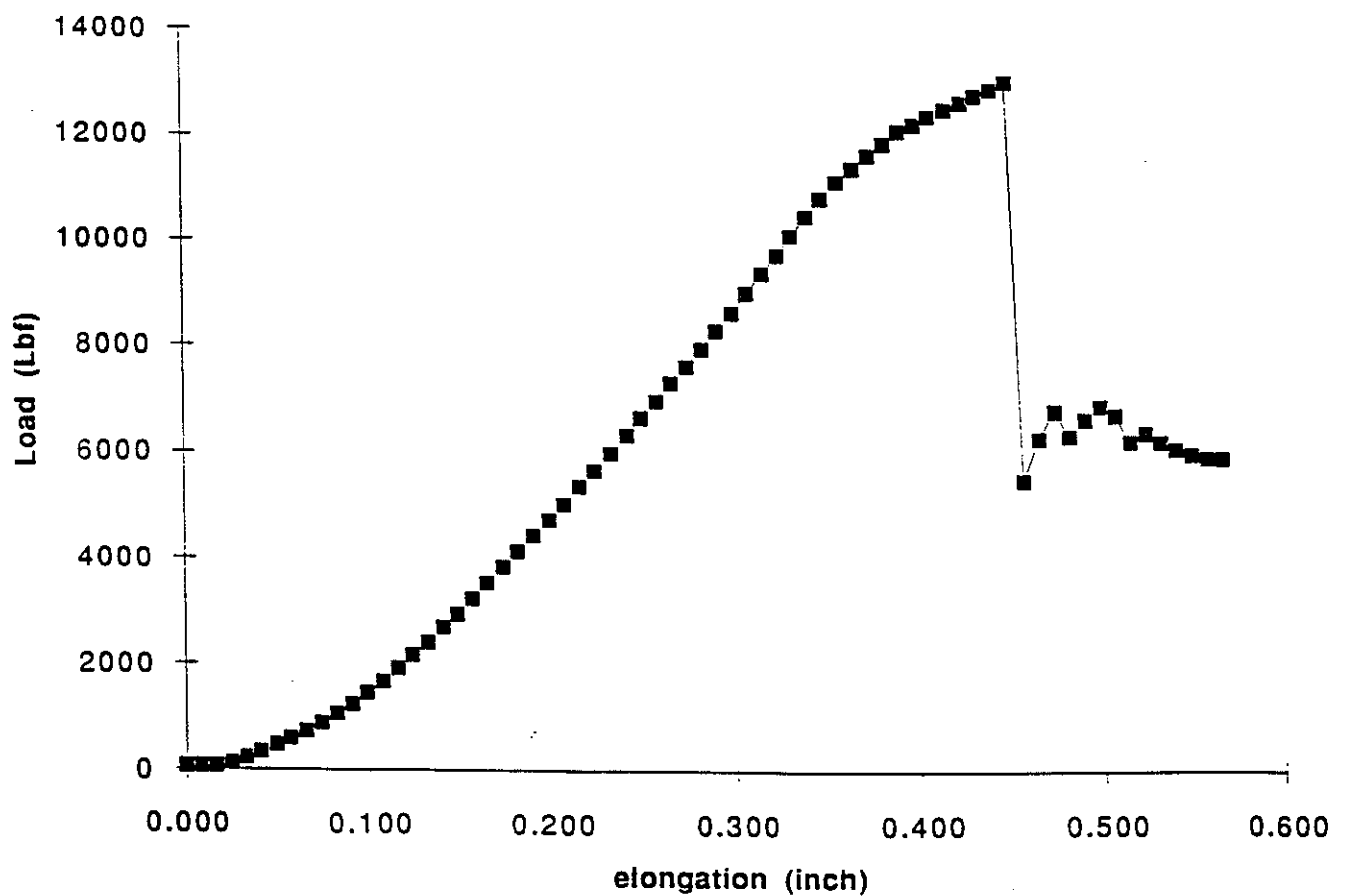




Kev7.7/16/93

	Fred Renken				
	16-Jul-93				
	Kevlar Test 7				
	Parallel count: 35				
	Perpendicular count: 34				
	Maximum Load 13.1 Kips				
	First Slip 13.1 kips				
	Standard Const—250 Ft•Lbs Torque				

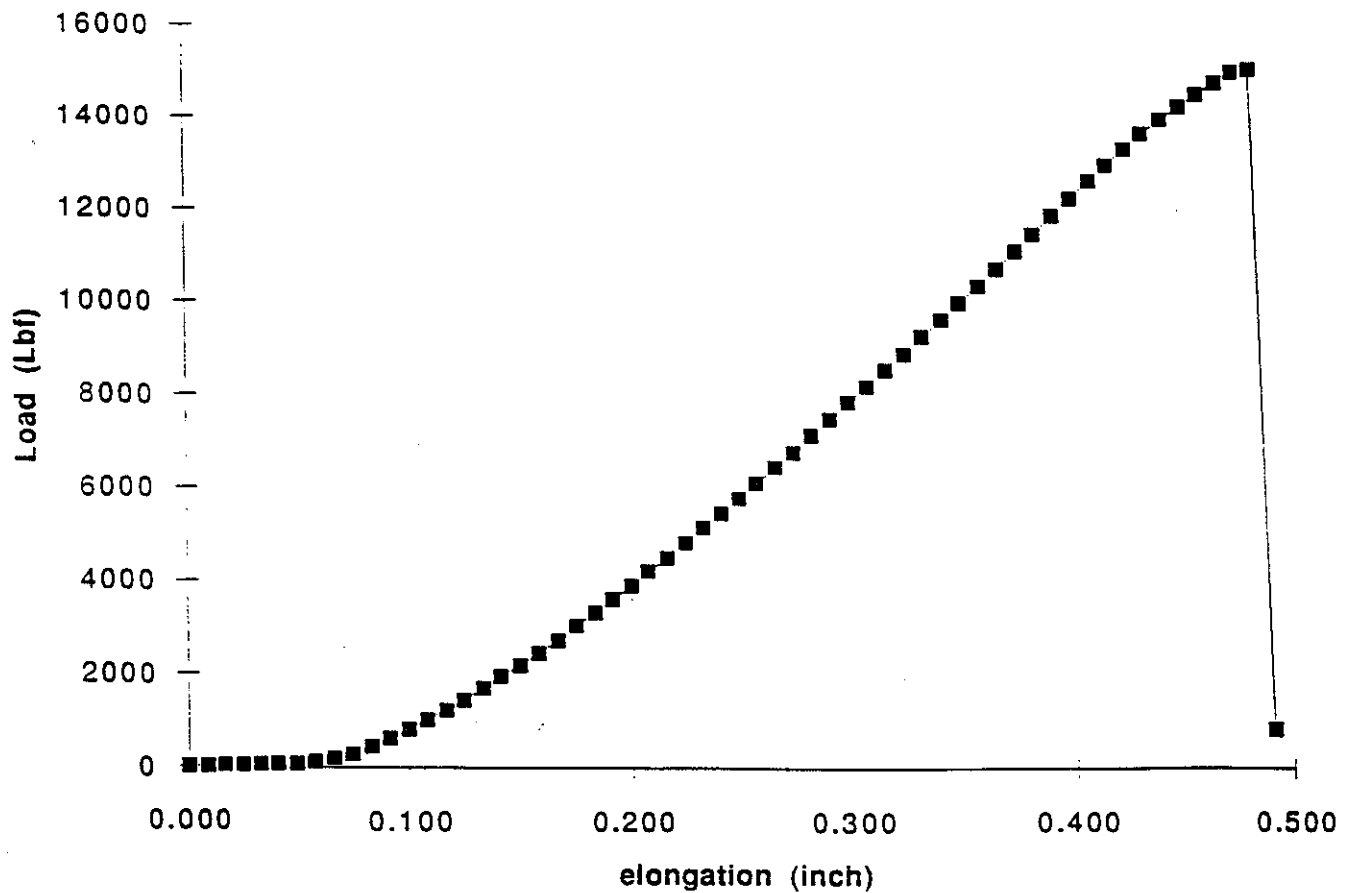
Kev7 Test Curve



Kev8.7/19/93

	Fred Renken				
	19-Jul-93				
	Kevlar Test 8				
	Parallel count: 35				
	Perpendicular count: 34				
	Maximum Load 15.25 Kips				
	First Slip 15.25 kips				
	Standard Const—250 Ft•Lbs Torque				

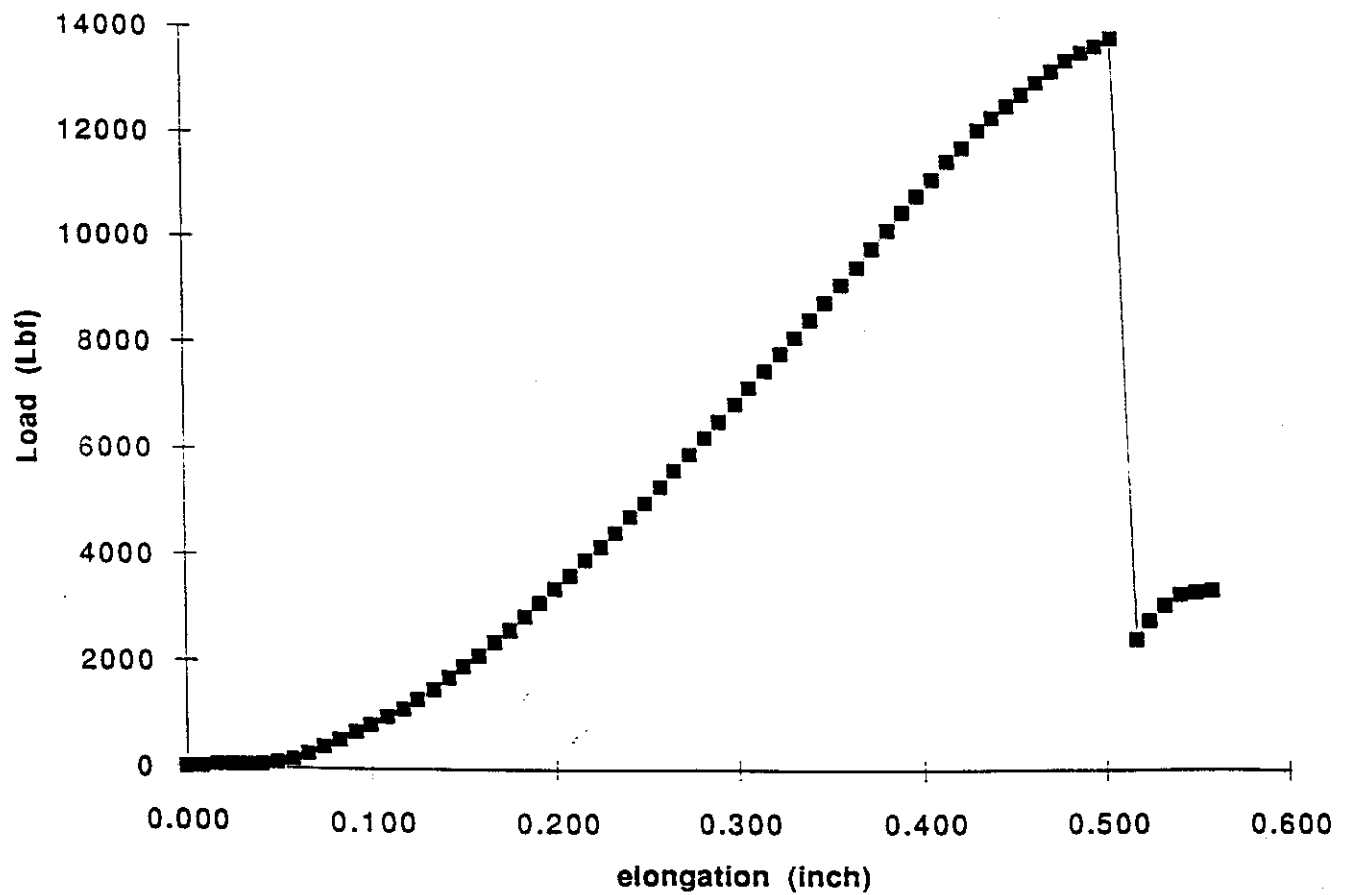
Kev8 Test Curve



Kev9.7/21/93

	Fred Renken				
	21-Jul-93				
	Kevlar Test 9				
	Parallel count: 35				
	Perpendicular count: 34				
	Maximum Load 13.96 Kips				
	First Slip 13.9 kips				
	Standard Const—250 Ft•Lbs Torque				

Kev9 Test Curve



STATE OF NEW YORK

IN SENATE, January 12, 1910.

REPORT  
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IN ANSWER TO A RESOLUTION PASSED BY THE SENATE,  
JANUARY 12, 1899.

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